

**THE FAMACHA METHOD AS A TOOL FOR SELECTING TREATMENT
OF *HAEMONCHUS CONTORTUS* INFECTION IN GOATS.**

BY

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ABSTRACT

The FAMACHA system was first developed in South Africa and it has been successfully tested in different geographic area where *Haemonchus contortus* is the major gastrointestinal (GI) helminth of sheep. The present study was aimed at using the FAMACHA method as a tool for selective treatment of *Haemonchus contortus* infection in goats. Each study animal was monthly subjected to blood and faecal sample collection, and all the animals were scored on a 1-5 scale with particular attention to the colour of ocular mucous membranes. The parasitological data included numbers of nematode eggs per gram of faeces (EPG), faecal culture L₃ larvae, packed cell volume (PCV), and FAMACHA eye-colour score estimates, along with animal performance (body weight change). There were 5 species of nematodes present in goats with *Haemonchus contortus* being the most prevalent (54–73%), followed by *Trichostrongylus* spp (10-20%), *Oesophagostomum* spp (7-10%), *Strongyloides* spp (4-8%) and *Bunostomum* spp (3-4%). The nematode infection (natural infection) showed that all the animals were positive for faecal egg, with the highest infection occurring during the raining season. Correlations between FAMACHA and PCV, FAMACHA and BW, EPG and PCV, EPG and BW, as well as FAMACHA and EPG, PCV and BW were all highly significant. ($P < 0.001$).

Faecal egg count reduction tests (FECRT) conducted on all farms visited confirmed the efficacy of commonly used anthelmintics, including imported albendazole, locally made albendazole 1, 2 and 3, Imported and locally made Levamisole and Ivermectin. Initially, high levels of resistance to all the benzimidazole group were found with percentage reduction of (65.90%, 93.81%, 59.94%, and -12.72%) respectively. While the levamisole, both imported and locally made had an efficacy of (98.5% and 99.5%), Ivermectin both injectable and drench had an efficacy of 99.51 and 97.45) respectively. Individual FECRT were also conducted on 4 goat flocks, 2 commercial and 2 local farms. There were 8 treatment groups in

each of these farms. All the 8 drugs were 100% effective against *Haemonchus contortus* in the 2 local farms. For commercial farm 1, Ivermectin drenched and injectable showed 100% and 99% effectiveness respectively against all worm species found, Imported and Locally made levamisole had 100% and 90% reduction respectively, Imported Albendazole had 94% reduction while the locally made albendazole (1,2 and 3) reduced faecal egg counts by 70%, 94% and 94%, respectively while for commercial farm 2 Ivermectin drenched and injectable showed 96% and 100% effectiveness respectively against all worm species found, imported and locally made Levamisole had 99% reduction each, imported Albendazole had a negative reduction of -35%, locally made Albendazole (2) had 97% efficacy while locally made albendazole (3) also had a negative reduction of -291%. It was therefore concluded that the FAMACHA method can be used by farmers in Nigeria as an on-farm tool to identify anaemic goats and give a guide on goats that need to be treated with anthelmintic particularly in condition of haemonchosis.

CHAPTER ONE

1 INTRODUCTION

1.1 Background of Study

Sheep and goat dairy production has a prominent role in the economy of several countries. However, they are influenced by several factors such as breeding methods, infectious and parasitic diseases (Park and Haenlein, 2006). Among the latter, gastrointestinal (GI) strongyle infection, caused by different genera of nematodes e.g, *Haemonchus*, *Trichostrongylus*, *Oesophagostomum* and *Strongyloides* remain one of the main constraints to sheep and goat production both in temperate and tropical countries (Rinaldi *et al.*, 2007).

The world's total numbers of goats and sheep were 861.9 and 1078.2 million respectively, i.e. there is about one goat to approximately 1.25 sheep. In Nigeria, the total number of goats and sheep were 53.8 and 33.9 million, respectively (FAOSTAT, 2008). This constitute 6.2% and 3.1% of the world total population of goats and sheep respectively (FAOSTAT, 2008).

The GI strongyle species of primary concern is *Haemonchus contortus*, a highly pathogenic blood-sucking helminth that causes anemia and reduced productivity leading to death in heavily infected animals (Burke *et al.*, 2007). *Haemonchus contortus* is a prolific egg producer and one female worm can produce up to 10,000 eggs per day, a probable reason why female worms tend to suck more blood than males (Roberts and Janovy, 2000). Thus a higher percentage of female than male worms is another contributory factor to blood loss and anaemia (Fetterer and Rhoads, 1996). About 400 worms can suck up to 6 ml of blood per day (Smyth, 1976) and at peak infection such populations may remove up to one fifth of the circulating erythrocytes volume per day

(Georgi and Georgi, 1990), each parasite being capable of sucking up to 0.05 ml of blood per day (Soulsby, 1982).

Previous results (Sharma, 1998; Arora *et al.*, 2003) reported that in India at the Central Institute for Research on Goat, Makhdoom, Mathura, the strongyle population is dominated by *H. contortus*. The larval differentiation from bulked cultures revealed that predominant larvae were *H. contortus* (96.2%), followed by *Strongyloides* spp. (1.6%), *Trichuris* spp. (1.2%) and *Oesophagostomum* spp. (0.02%). Another study by Kumsa and Wossene (2006) revealed a very high overall prevalence of 92.9% and 90.2% of abomasal nematodes in sheep and goats, respectively in semiarid region of eastern Ethiopia. The observed very high prevalence rate is in line with previous studies conducted by Solomon (1987), who reported 90 %, Donald (1999), and Abebe and Esayas (2001), reported more than 90% prevalence of abomasal parasites in the Eastern part of Ethiopia suggesting that the semiarid Ogaden region is conducive environment for rampant abomasal nematodes of sheep and goats. Musongong *et al.* (2011) reported a prevalence of (81.5%) in sheep, and (54%) in goat in the arid zone of Maiduguri. Chiejina (1993) reported 90-100% prevalence of *H. contortus* in eastern Nigeria, Ajanusi and Chiezey (2005) reported 89.1% prevalence of *H. contortus* in goats in Zaria.

A decrease in profitability up to 15% and weight loss up to 50% due to gastrointestinal parasites have been reported by Hussain (1985). Economic losses amounting to Rs. 19.7 millions per year have been estimated by Iqbal *et al.*, (1993). Javed *et al.*, (1992) found that losses associated with lowered meat and wool production in sheep and goats in Faisalabad (Pakistan) was amounting to 31.4 million per year.

One method of controlling gastrointestinal Strongyles in small ruminants is based upon treatments with anthelmintics, which has led to the development of drug-resistant worm populations throughout the world (Mortensen *et al.*, 2003; Kaplan *et al.*, 2004). Anthelmintic resistance has been described as the Heritable ability of worms to survive a dose of anthelmintic which would normally be effective (Coles, 2006). Based on published data, *Haemonchus contortus* seems to be the species most involved in cases of anthelmintic resistance (Cabaret, 2000).

Targeted selective treatments (TST) have been recently proposed in order to reduce anthelmintic usage helping to maintain populations in refugia. The concept of refugia has been largely used in biological control and Agricultural Entomology (Gould 2000; Hazelby *et al.*, 1994; Tang *et al.*, 2001); Hoste *et al.*, 2002; Juraj *et al.*, 2002, phylogeography (Walter *et al.*, 2001), conservation biology Griffith, (2000), and ecology (Schneider *et al.*, 1999). It corresponds to the fraction of the nematode population that is not submitted to selection pressure by a control measure (Coles and VanWyk *et al.*, 2000). The concept presents a spatial and temporal component when digestive-tract nematodes are considered: the part of the population in refugia corresponds to the free-living stages, located on pastures and not submitted to the anthelmintic treatment given to the hosts. The size of the population in refugia at the time of the anthelmintic treatment will determine the contribution of the surviving worms to the subsequent generation: this was presented by Van Wyk, (2001) as a major source of resistance. This in turn would help to conserve the genes for susceptibility within parasite populations (Van Wyk and Bath, 2002).

By far the best known example of Targeted Selective Treatment (TST) indicator is FAMACHA-an acronym derived from the name of the idea, Dr. Faffa Malan (Faffa

Malan CHArt)-a system developed in South Africa that uses anemia, determined on the basis of the colour of lower eyelid mucous membrane in small ruminants. This is a diagnostic morbidity marker for haemonchosis (Bath *et al.*, 1996; Malan *et al.*, 2001; Vatta *et al.*, 2001; VanWyk and Bath, 2002). Since its development, it has been successfully tested in countries and regions where *Haemonchus contortus* is the major gastrointestinal strongyles species of sheep and goats. Its use in the field has been shown to reduce the numbers of treatments required and offers the prospect of maintaining a parasites population in refugia in those animals that do not require treatment (Van Wyk and Bath 2002; Kaplan *et al.*, 2004). Besides South Africa, where the method was developed also by Bisset *et al.*, (2001), the FAMACHA system has been recently studied for management of *Haemonchus contortus*-infected small ruminants in Kenya (Ejlertsen *et al.*, 2006), Ethiopia (Sissay *et al.*, 2007), United States (Kaplan *et al.*, 2004; Burke *et al.*, 2007), Brazil (Sotomaior *et al.*, 2003; Molento *et al.*, 2004), and Germany (Gauly *et al.*, 2004; Koopmann *et al.*, 2006). In all these previous studies, the packed cell volume (PCV) was the only haematological parameter used for detecting the severity of anemia in order to evaluate the FAMACHA system.

Although the first studies on FAMACHA showed a high accuracy of this method. Koopmann *et al.*, (2006) found that in Germany, at a comparatively low prevalence of *Haemonchus contortus*, the FAMACHA test proved not to be sufficient in detecting all animals with high faecal egg counts.

1.2 Statement of Research Problems

Gastrointestinal nematodes of which *Haemonchus contortus* ranks highest in importance globally (Perry *et al.*, 2002; Tariq *et al.*, 2010) are recognized as a major constraint to both small and large-scale small ruminant production in developing

countries, leading to significant economic losses (Martinez-Gonzalez *et al.*, 1998). These nematodes (Mainly *Haemonchus*, *Trichostrongylus* and *Cooperia*) cause impaired digestion and also affect the absorption of minerals particularly calcium and phosphorus (Speedy, 1992).

Surveys indicated that up to 95% sheep and goats in the tropics are infected with helminths and, *Haemonchus* and *Trichostrongylus* are the main genera involved (Rey, 1991). Mortality rates in herds may exceed 40%, while weight losses of up to 6-12 kg/year/animal may occur (IEMVT, 1980). In Nigeria, the economic loss due to helminthosis in small ruminants alone has been estimated to be at least 144 million naira annually, through death, weight loss and liver condemnation (Akerejola *et al.*, 1979).

Ajanusi and Chiezey (2005), carried out a study on prevalence of *Haemonchus contortus* and some haemosporozoan (*Anaplasma ovis* and *Theileria ovis*) infections in goats in Zaria and obtained a prevalence of 89.1%, 9.2% and 3% respectively. These reports indicate a high prevalence of gastrointestinal parasitism in goats which may be contributing to low productivity of these animals.

Ebbo *et al.* (2003) and Useh (2005) reported a high incidence (60%) of gastrointestinal parasitism in small ruminants presented for clinical examination at the Usman Danfodio University Veterinary Teaching Hospital (VTH), Sokoto, and ABU VTH Zaria, respectively.

Studies on sheep and goat farms in the Southern United States indicate that multiple anthelmintic resistance in *Haemonchus contortus* is becoming a serious problem. Though many factors are involved in the development of resistance, the proportion of parasite population with drug selection is believed to be the single most important factor

influencing how rapidly resistance develops (*Kaplan et al., 2004*). Therefore, where prevention of resistance is an important parallel goal of worm control, it is recommended to have a portion of the animals untreated.

Since most studies validating the FAMACHA method have been performed in South Africa, Kenya, Ethiopia, USA, Brazil and Germany, it is important that the method be tested in other regions to determine optimal strategies for incorporating it as a diagnostic tool for a based selective treatment protocols into integrated nematode control programs. (*Kaplan et al., 2004*).

1.3 Justification of the Study

Helminthes infections constitute a major disease problem to domestic livestock worldwide (*Perry et al., 2002*), with most grazing livestock being at risk from infection of gastro-intestinal (GI) nematode parasite.

Gastro-intestinal nematodes and particularly the stomach worm *H. contortus* are a major constraint in small ruminant production worldwide including Nigeria (*Pralomkarn et al., 1997*; *Chauban et al., 2003*).

In Nigeria, gastro-intestinal nematode infection is one of the major health problems. *Gillian et al., (2004)* reported that nematode infections affect the health of millions of people and animals, causing huge economic loss in livestock farming. Also, *Mulugeta et al., (1989)* reported that infection is enormous in small domestic ruminants, causing major production loss.

Over reliance on dewormers in the past led to the development of anthelmintic resistant gastro-intestinal nematodes (GIN); (*Mortensen et al., 2003*; *Kaplan, 2004*). There is a growing interest by producers and consumers for meat animals with minimal drug input

to reduce drug residues in the meat and to increase the sustainability of livestock production (Green and Kremen, 2003).

Efforts are now being made to selectively upgrade and rear helminth-resistant breeds of goat and sheep (Shavulimo *et al.*, 1988; Fakae *et al.*, 2003). The frequency of drug administration, under dosing, prohibitive cost of chemotherapy and presently, the influx of fake and adulterated drugs in Nigeria had given rise to the development of resistance to the currently used anthelmintics by the worm (Ikeme, 1997). An alternative approach is urgently needed, therefore, to check the rising frequency of resistant genes in the nematode population (Ikeme, 1997).

This study therefore focuses on providing information on how to select which animals infected with *Haemonchus contortus* are to be treated in order to avoid the development of anthelmintic resistance and to hopefully restore anthelmintic efficacy in the future.

1.4 Aim of the Study

To use the FAMACHA method as a tool for selecting treatment of *H. contortus* infection in goats with a view to manage the infection.

Specific Objectives

Specific objectives were:

- 1- To use the FAMACHA scores of Red Sokoto and Sahelian breeds of goats in a research institute.
- 2- To correlate differences between PCV, FEC, Body Weight and FAMACHA Scores of goat in a Research Institute, Zaria and other sampling units.
- 3- To determine the status of anthelmintic efficacy in the selected flocks using the faecal egg reduction test (FERT),

- 4- To establish the helminthes at copro-culture amongst Goats in a Research Institute, Zaria and other Sampling Units.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Helminths

The name “helminth” is derived from the Greek word “helmins” or “helminthos”, meaning a worm, and is usually applied only to the parasitic and non-parasitic species belonging to the phylum Platyhelminthes (such as flukes and tapeworms) and the phylum Nematelminthes(roundworms and their relatives). The Annelida(earth worms, leeches) are basically different from both the Platyhelminthes and Nematelminthes and are not regarded as helminthes, though some (e.g. leeches) may be parasitic and others (e.g. earthworms) may serve as intermediate hosts for helminths (Soulsby, 1986; Urquhart *et al.*, 1996).

Therefore, helminth infections, or helminthoses, thus refer to a complex of conditions caused by parasites belonging to the class Nematoda, Cestoda and Trematoda. Although all grazing sheep and goats may be infected with helminths, low worm burdens usually have little impact on animal health. With heavier worm burdens however, clinical signs such as weight loss, diarrhoea, anaemia, or sub-mandibular oedema (bottle jaw) may develop (Sissay, 2007).

Domesticated animals harbour a wide range of parasites, most important of which are helminths. Helminth parasites are by far the most serious cause of production losses in farm ruminants (Familton and McAnulty, 1997) and nematodes are the most important of these. Internal parasitism is the major disease syndrome of pastoral ruminants simply

because environments which favour pastoralism also favour the survival and development of the free-living stages of helminth parasites (Sykes, 1997).

This review is confined to helminth parasites (Gastrointestinal nematodes) of goats. The internal parasites of concern fall into the Strongyle group, with *Haemonchus contortus* being by far the most important. Goats can be infected with many of the same worms as sheep, and they can transmit them to each other (Mason, 1997b; Pomroy, 1997a).

2.2 Aetiology of Helminthoses

Helminthosis is a widespread infection of small ruminants in the sub-Saharan region. Nematoda, trematoda and cestoda are the three major classes of parasitic helminths of economic and zoonotic importance affecting goats and sheep in this region (Anene *et al.*, 1994).

The Nematelminthes (nematodes) include several superfamilies of Veterinary importance. These are Trichostrongyloidea, Strongyloidea, Ancylostomatoidea, Metastrongyloidea, Rhabditoidea, Trichuroidea, Filarioidea, Oxyuroidea, Ascaridoidea and Spiruroidea. The GI nematodes of greatest importance in small ruminants are members of the Order Rhabditida, suborder Strongylida, which contains the first four superfamilies, but the most important species belong to the superfamily Trichostrongyloidea. All grazing sheep and goats are infected with a community of these strongylid nematodes, whose combined clinical effect is the condition known as parasitic gastroenteritis (PGE) (Zajac, 2006).

The most common species of nematodes associated with parasitic gastro-enteritis in small ruminants in most sub-Saharan countries are *Haemonchus contortus*, *Oesophagostomum columbianum* and *Trichostrongylus colubriformis*. *Trichostrongylus axei*, *Bunostomum trigonocephalum*, *Cooperia curticei*, *Trichuris ovis*, *Trichuris*

globulosus, *Strongyloides papillosus*, *Gaigeria pachysceli* and *Chabertia ovina* also contribute to the syndrome (Soulsby, 1982; Chiejina, 1986; Hansen and Perry, 1994; Nwosu *et al.*, 1996a,b; Lughano and Dominic, 1996). In winter rainfall and cool highland areas, *Ostertagia circumcincta* and *Nematodirus filicollis* are also involved in the pathogenesis of parasitic gastro-enteritis in goats and sheep (Bekele *et al.*, 1992; Tembely, 1995; Tembely *et al.*, 1997).

The most important cestode parasites of small ruminants, both in terms of public health and Veterinary medicine, belong to the family Taeniidae. *Stilesia hepatica* and *Moniezia expansa* are the common parasitic cestodes encountered in goats in the sub-Saharan region (Urquhart *et al.*, 1996). *Moniezia expansa* infection is very common in kids and heavy infection with the parasite causes unthriftiness (Fabiya, 1970).

2.3 Nematodes (roundworms)

2.3.1 General morphology

In general, the nematodes are the most numerous animals on earth (Smyth, 1962; Jasmer *et al.*, 2003). Nematodes make up a large assemblage of worms of relatively simple structure with a widespread distribution, their cylindrical, non-segmented bodies distinguishing them easily from other helminthes. They occur in fresh water, in the sea, in the soil, and are amongst the most successful parasites of plants and animals (Smyth, 1962). The morphology of nematodes, the body is elongated, cylindrical and tapered at the extremities. The body is also unsegmented and covered with cuticle which is thick and continuous with the cuticular lining of the buccal cavity, the oesophagus, the rectum and the distal portions of the genital ducts (Jacobs *et al.*, 2003).

Roundworms consist of an external membrane, a cortex, a matrix and fibre stratum (Soulsby, 1986), divisible into nine distinct layers. The cuticle consists of an underlying

sub-cuticle layer, the hypodermis, which consists of cells in the free-living form and a syncytium containing a number of nuclei in the parasitic forms. This layer has the longitudinal lines located, dorsally, ventrally and laterally. The lateral line contains the longitudinal canals of the excretory system (<http://www.ucmp.berkeley.edu>).

The muscular layer which follows next and lines the body cavity consists of a number of cells having a basal contractile portion which is transversely striated and a cytoplasmic portion which contains the nucleus and is connected to the nerve trunks running in the dorsal or ventral line. The mouth is anterior and usually surrounded by three lips, one dorsal and two ventral. In other forms there are only two lips or lips may disappear completely (*Strongyloides*). The mouth may lead into a buccal capsule which has thick cuticular walls and may contain special teeth, or into the pharynx, which is usually cylindrical and surrounded by muscular tissue, or directly into the oesophagus. The oesophagus of nematode parasites shows variations in structure that are used for the classification of species (Sandground, 1925).

The oesophagus is a strongly muscular organ lined with a cuticle which divides the wall into one dorsal and two ventral sectors. The wall of the oesophagus contains three oesophagus glands, which secrete digestive enzymes. The intestine is a simple tube with a non-muscular wall composed of a single layer of columnar cells standing on a basal membrane. It leads to the rectum which is lined with cuticle and to the genital duct ending with a cloaca. The part of the body behind the anal or cloacal opening is called the tail (Soulsby, 1986).

2.3.2 Nematodes of the abomasum

2.3.3 *Haemonchus contortus* (Family: Trichostrongylidae)

Haemonchus contortus (known as the Barber's pole worm, wire worm or the red stomach worm) is a very common parasite and one of the most pathogenic nematode of ruminants, found in the abomasum and occurs in nearly all subtropical and temperate areas of the world. In Middle Europe *H. contortus* is present in 50-75% of small ruminants (Eckert *et al.*, 2008).

Adult worms are attached to abomasal mucosa and feed on blood, which causes anaemia and eventually can lead to death, thus making *H. contortus* one of the most pathogenic nematodes of ruminants. *Haemonchus contortus* also possess the ability to rapidly develop resistance against anthelmintics (Coles *et al.*, 2005).

The egg is yellowish in colour, approximately 70–85 µm long by 44 µm wide, and in the early stages of cleavage contain between 16–32 cells. The female adult worms are 18-30 mm long and may lay over 5,000 eggs per day. They are slender worms with a small buccal cavity, 3 lips and a lancet. In the female, the vulva is in the posterior half of the body, covered by the vulval flap, a characteristic feature of the female. The white ovaries wind spirally around the red intestine, giving the characteristic barber's pole appearance (Soulsby, 1986).

The male adult worm is much smaller, at 10–20 mm long and displays the distinct feature of a well-developed copulatory bursa, containing an asymmetrical dorsal lobe and a Y shaped dorsal ray, (plate 2.1 and 2.2). Spicules are 0.46 to 0.51 mm long, each terminating in a small barb. Buccal capsule when present is reduced or rudimentary and there are usually no teeth in the buccal capsule but a minute dorsal lancet (Ukoli, 1984).

The main clinical signs of acute haemonchosis are anaemia, variable degrees of oedema, lethargy, dark coloured faeces and wool break. Chronic cases show weight loss and weakness. (Noble and Noble, 1982; Eckert *et al.*, 2008).

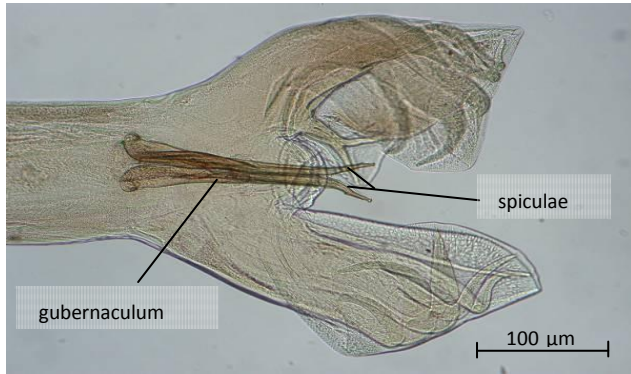


Plate 2.1: copulatory bursa of male adult *H. contortus* found in the abomasum of goat that died of acute haemonchosis.

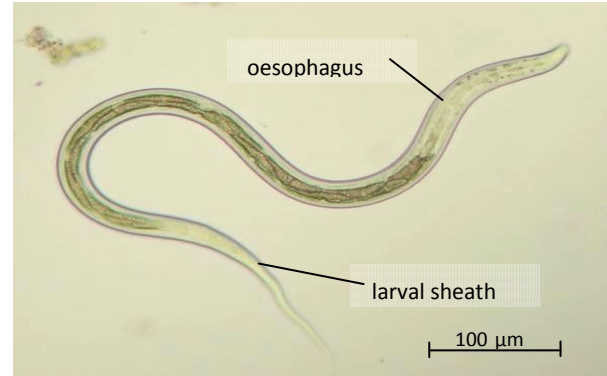


Plate 2.2: Third-stage larva of *H. contortus* collected from Coproculture

2.3.3.1 *Trichostrongylus axei* ('stomach hair worm')

Trichostrongylus axei occurs commonly in the abomasum of ruminants, often in association with *Haemonchus* and *Ostertagia*, and also in other host species, such as horses, but appears to be relatively non-pathogenic. Adult *T. axei* are very small, (smaller than *Haemonchus* and *Ostertagia*), slender, hair-like and reddish-brown with small anterior ends and no buccalcavity. Males measure 4 - 7 mm long and females 5 - 8 mm. Often, eggs can be observed in the body of the worm (Love and Hutchinson, 2003). Eggs are most often 73 to 95 μm in length and about 40 μm in width. Male worms can be recognized by their asymmetrical dorsal ray and two short nearly equal spicules. *Trichostrongylus axei* is present in about 25-50% of the small ruminants (Rehbein *et al.*, 1998) and may also occur in small intestine (Soulsby, 1986).

2.4 Life Cycle of Helminths

2.4.1 Life cycle of gastrointestinal nematodes

To develop effective and sustainable control programmes against helminth parasites, it is important to have a good knowledge of their life cycle both within and outside the

host animal (Familton and McAnulty, 1997; Vlassoff *et al.*, 2001). The life cycle can be seen below, (figure 2.1).

With the exception of *Nematodirus*, the gastrointestinal nematodes have a similar basic life cycle with no intermediate hosts. The adult nematodes inhabit various regions of the gastro-intestinal tract. The mature parasites (worms) breed inside the host and lay eggs which pass through the host and are shed in the faeces. After the eggs pass out of the host, they hatch into first-stage larvae (L₁) and moult into second-stage larvae (L₂) under appropriate conditions of temperature and humidity. The larvae need moisture to develop and move. During this time the larvae feed on bacteria. The L₂ moult into the infective larvae (L₃). When the last moult is completed, the L₃ have a protective cuticle around them. Consequently they cannot feed and rely on stored energy sources. Development ceases until the L₃ larva is ingested by its potential future host. These larvae are about 1 mm in length and many migrate out of the faeces and swim in moisture on to the herbage (Brunsdon *et al.*, 1975; Vlassoff, 1982, 1998; Familton and McAnulty, 1997; Pomroy, 1997a; Vlassoff *et al.*, 2001; Sissay, 2007).

Upon ingestion by the susceptible host during grazing, the protective covering of the L₃ is removed through a process called exsheathment. The exsheathing fluid is produced by the host and exsheathment occurs in the part of the GIT that is immediately anterior to the helminth's predilection site. They thereafter, moult into the fourth-stage larvae (L₄) within 2-3 days, remaining for further 10 - 14 days to moult into young adult parasites (Soulsby, 1986; Hale, 2006; Coffey *et al.*, 2007). Thus, after ingestion, the L₃ of *Haemonchus spp* and *Trichostrongylus axei* develop through the fourth (L₄) and fifth (L₅) stage larvae and mature into adults in the abomasum while the maturation of *T. colubriformis* and *Oesophagostomum spp* occur in the small and large intestines

respectively. The prepatent period for most gastro-intestinal trichostrongyles is about 21 days.

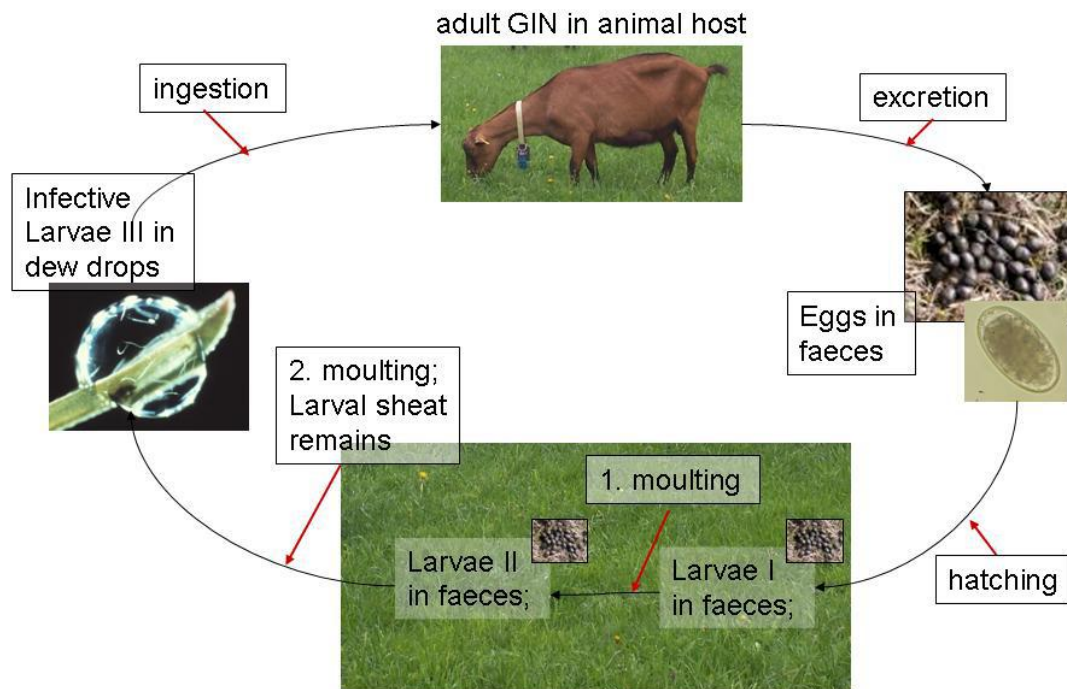


Figure 2.1: General life cycle of gastrointestinal nematodes of small ruminants. L₁, L₂ and L₃, stand for first, second and third larvae stage.

2.5 Epidemiology of Helminths

Epidemiology is defined here as the study of the dynamic changes which occur both within the host and within the environment. Understanding epidemiology allows us to appreciate the complexity of developing control programmes which work (Familton and McAnulty, 1997; Vlassoff *et al.*, 2001).

2.5.1 Epidemiology of gastro-intestinal nematodes

A study of epidemiology necessitates an intimate knowledge of the life cycle of a parasite. The epidemiology of gastrointestinal nematode (GIN) infections is influenced by environmental factors (particularly rainfall, humidity and temperature), management

systems used for the animal, host factors and parasite factors (Familton and McAnulty, 1995).

Osakwe and Anyigor, (2007), also identified five major factors that have been associated with the prevalence of the parasites namely: poor system of management, illiteracy, lack of deworming programmes, non-commercial purpose of keeping goats and very old farmers in the business. Over 90% (up to 99%) of the total parasite population exists outside the ruminant host (Familton and McAnulty, 1995, 1996, 1997; Vlassoff, 1998) as eggs or larvae in the faeces or in the soil. Even under arid Australian conditions, only 3% of the population in a haemonchosis outbreak lived within the host animal (Le Jambre, 1978).

The important facts of epidemiology of GIN infections have been well described by several workers in various geographical zones of the world, such as Gambia (Fritsche *et al.*, 1993), Saudi Arabia (El-Azazy, 1995), the Plateau areas of Togo (Bonfoh *et al.*, 1995), the Senegal tree-cropping pasture zone (Ndao *et al.*, 1995), Peninsular Malaysia (Dorny *et al.*, 1995), France (Hostel *et al.*, 2001), America (Miller *et al.*, 1998), Sweden (Lindgvist *et al.*, 2001; Waller *et al.*, 2004), Central Kenya (Nginyi *et al.*, 2001), the Coastal Savannah regions of Ghana (Agyei, 2003), South Africa (Tsotetsi and Mbatia, 2003), Semi-arid area of Kajiado district of Kenya (Ng'ang'a *et al.*, 2004) and Nigeria (Fakae, 1990). The epidemiology of nematode helminths is affected by several factors.

2.5.1.1 Environmental factors

In Nigeria, helminth parasites of small ruminants are ubiquitous in all of the agro-climatic zones with prevailing weather conditions that provide favourable condition for their survival and development. The effect of environmental factors on survival and development of larvae on pasture has been documented (Eysker and Ogunsusi, 1980).

Fabiyi (1973), also reported a distinct seasonal fluctuation in nematode infection in goats in Zaria. The three most important factors influencing egg hatching, development and survival of nematode larvae are rainfall/moisture, oxygen, and temperature (Familton and McAnulty, 1997).

2.5.1.2 Climatic factors

Rainfall or moisture: is the most important factor which influences the survival, development, dissemination and availability of free- living stages of helminths. Moisture facilitates horizontal and vertical migration of nematode larvae in the environment.

Optimal levels of moisture and oxygen probably occur at different times within the decaying faeces, and may account for the different time periods over which eggs hatch and larvae develop (Familton and McAnulty, 1997). In moist environments a larger proportion of the eggs will develop to the infective larval stage. In very dry summers, larvae may develop successfully to the infective stage in faeces, but do not emerge until moisture levels are optimal. Infected faeces continue to be passed by the host, so that when moisture is available, pasture contamination by larvae can rise very rapidly (Michel, 1982). In dry conditions, the surface of the faeces desiccates providing a protective crust which prevents drying out of the interior of the faecal mass and also prevents release of the infective larvae (Gronvold, 1989). This situation may continue until water breaks down the crust allowing larval release.

Temperature: Temperature has a big influence on egg hatching, larval development and the subsequent survival of the pre-parasitic stages (Vlassoff, 1982). The preferred developmental conditions of different nematode species vary and are reflected in their

distribution and relative abundance from season to season and year to year (Vlassoff, 1982; Vlassoff *et al.*, 2001).

For successful development of eggs and pre infective stages into L₃ larvae in faeces, they must survive a range of climatic conditions (Vlassoff and Bisset, 1991; Vlassoff *et al.*, 2001). Optimal development occurs between 15°C and 30°C, but development will take place at varying rates within the temperature range of 4°C to 35°C if moisture is present (Vlassoff, 1982). Eggs of *Haemonchus*, *Trichostrongylus*, *Ostertagia* and *Chabertia* spp develop to L₃ larvae most rapidly at mean monthly air temperatures of 15°C - 24°C. Below 10°C, development is slow, and most eggs fail to hatch.

Eggs and larvae of most species of gastro-intestinal parasites of sheep (with the exception of *Haemonchus contortus*) tolerate cold temperatures but their metabolic rate is reduced (Familton and McAnulty, 1997; Pomroy, 1997a).

Some trichostrongylid larvae such as *Trichostrongylus colubriformis* and *Oesophagostomum columbianum* are known to be resistant to desiccation and this ability enables them to survive under extremely low or high temperature.

Oxygen: Oxygen is necessary for the development of eggs and lack of oxygen inhibits hatching, subsequent larval development and larval activity (Familton and McAnulty, 1997).

2.5.1.3 Management systems

Management systems for animals have a strong influence on the epidemiology of gastro-intestinal nematodes. High stocking density increases the contamination of the environment with nematode eggs or larvae and thus making the infective stages to be more accessible to susceptible animal. High stocking rates and intensive management

with little or minimal rotational grazing, are associated with high pasture contamination and outbreaks of clinical helminthosis. On the other hand, low stocking rates and extensive management systems in the traditional husbandry systems preclude a build-up of high worm burdens. The concentration of animals at watering points particularly during the dry season may also result in massive contamination of pastures with eggs or larvae leading to outbreaks of parasitic gastro-enteritis. Tethering of goats and sheep during the wet season which is common in many agro-pastoral societies have been reported to result in increased environmental contamination with infective larvae and incidence of clinical disease. Outbreaks of parasitic gastro-enteritis in such systems have been reported in Tanzania, Nigeria, Kenya and Cameroon (Connor, 1985; Ndamukong, 1987; Chiejina *et al.*, 1988; Okon, 1988; Fakae, 1990; Hansen and Perry, 1994)

However, if tethered animals are moved each day to fresh ground and the number of animals in the area is small, the risk of helminthosis is reduced. Similarly, if animals are totally confined and fed on diets free of infective helminth larvae the risk of helminthosis is reduced.

2.5.1.4 Anthelmintic treatment

Anthelmintic treatment reduces the prevalence and severity of gastro-intestinal nematode infections and may significantly influence their epidemiology. However, the effectiveness of anthelmintic treatment regimes depends on a thorough knowledge of other factors which influence the epidemiology of nematodosis. Indiscriminate use of anthelmintics may result in the development of resistant nematode strains and this problem is increasing in importance across the sub-Saharan region (Ikeme, 1997).

2.5.1.5 Host factors

The incidence rate and severity of infection with gastro-intestinal nematodes can be influenced by host factors such as age, breed, sex, nutrition, physiological state and presence or absence of intercurrent infection.

Age: A number of authors have demonstrated an increased prevalence in young animals. Asanji and Williams (1987), stated that young animals are highly susceptible due to immunological immaturity and immunological unresponsiveness. Urquhart *et al.* (1996); Taswar *et al.* (2010) and Dagnachew *et al.* (2011), have documented that adult animals develop acquired immunity against helminth infections as they mature due to repeated exposure and which helps to expel the parasite before it establishes itself in the GIT. For instance, kids and lambs are known to be more susceptible than adult and there is a tendency for the worm burdens in goats and sheep to decrease with increasing age (Schmidt and Robberts, 1985; Schmidt *et al.*, 2000; Nwosu *et al.*, 2006). On the contrary, there are instances where younger animals were reported to be resistant to parasitic infection (Taswar *et al.*, 2010).

Breed: There is an increasing evidence for genetic variation in resistance to nematodes in sheep and goats (Baker *et al.*, 1998, 2001; Bishop and Morris, 2007). Genetic variation for resistance to GI parasites has been established between breeds (Pralomkarn *et al.*, 1997; Baker *et al.*, 1998, 2001; Costa *et al.*, 2000; Chauhan *et al.*, 2003) and within breeds (Morris *et al.*, 1997; Mandonnet *et al.*, 2001; Rout *et al.*, 2002; Chauhan *et al.*, 2003).

Some breeds of goats and sheep are known to be genetically resistant to gastro-intestinal nematode infections than others. It has been demonstrated in Kenya that the Small East African (SEA) goats are more resistant to *H. contortus* infection than their crosses with the Toggenburg and the Galla goats. Sheep also develop a strong natural immunity

around 12 months of age. Goats acquire a lower level immunity to gastro-intestinal parasites. This could result in goats having greater populations of adult parasites with high egg output (Macaldowie *et al.*, 2003). The West African Dwarf goats and sheep are known to be resistant to gastro-intestinal nematode (Lughano and Dominic, 1996; Chiejina *et al.*, 1986).

Sex:Most of the researchers have observed higher rates of nematode infection/worm burden in female hosts compared with the males (Maqsood *et al.*, 1996; Komoin *et al.*, 1999; Valcarcel and Romero, 1999). However, Gulland and Fox (1992), reported that prevalence and intensity of infection (faecal egg counts) were higher in males than females, except during the lambing periods, and decreased with age in both sexes. Sex is a determinant factor influencing prevalence of parasitism (Maqsood *et al.*, 1996) and females are more prone to parasitism during pregnancy and periparturient rise due to stress and decreased immune status (Urquhart *et al.*, 1996). Dagnachew *et al.* (2011) reported a higher prevalence of helminth infection in females.

Physiological status:The physiological status of the animal may influence its susceptibility of gastro-intestinal nematode infections. Hormonal changes during late pregnancy and lactation lower the resistance of the host to nematodes and consequently result in the establishment of higher worm burdens (Coop *et al.*, 1990). Prolactin and glucocorticoids are considered to be modulators of periparturient egg rise in goats and sheep. The increase in the fecundity of adult worms already in the alimentary tract and non-specific immunological loss of resistance by does and ewes as a result of stress associated with lambing and kidding are also considered to be responsible for the post parturient rise in faecal egg count in does and ewes. On the other hand, oestrogens have

been found to be responsible for the resistance of female hosts to gastro-intestinal nematodes (Lughano and Dominic, 1996).

Nutrition: Poor nutrition lowers the resistance of the animal thus enhancing the establishment of worm burdens and increasing the pathogenicity of the parasites. It is well known that adequately fed animals are more able to tolerate parasitism than animals on a low plane of nutrition (Knox and Steel, 1996; Waruiru *et al.*, 2004; Knox *et al.*, 2006). Thus, small ruminants affected by blood-sucking parasites, such as *H. contortus*, may be able to maintain their haemoglobin levels as long as their iron and protein intakes are adequate. However, if the animals' iron reserves and protein intake are reduced then their haemopoietic systems become exhausted, and they may die (Abbott *et al.*, 1986; Gibbs and Barger, 1986; Rowe *et al.*, 1988; Vatta *et al.*, 2002).

Consequently, worm burdens tend to be higher in poorly fed than in well fed animals. In Nigeria, Sierra Leone and Kenya, malnutrition during the dry season has been found to lower the resistance of goat and sheep to *H. contortus* infection resulting in heavy mortalities while restricted feeding due to tethering during the rainy season has been associated with high nematode burdens and mortality of goats (Lughano and Dominic, 1996).

2.5.1.6 Parasite factors

The intrinsic multiplication rate of a nematode species determines its rate of establishment and size of its burden in the host. The multiplication rate is determined by the fecundity of the adult worms, the prepatent period and the survival and the development rate of the parasite in the environment. For example, *H. contortus* and *Oesophagostomum columbianum* have a high biotic potential such that establishment of these nematodes occurs very rapidly as long as environmental factors are favourable.

Trichostrongylus spp has a lower biotic potential and hence its establishment is lower (Lughano and Dominic, 1996).

2.5.2 Hypobiosis in Parasitic Nematodes

Successful transfer from an infected host to a susceptible one represents a most important achievement in the parasitic way of life. Any developmental adaptation which serves to facilitate this process is, therefore, extremely important in the epidemiology of these infections (Gibbs, 1986).

Hypobiosis or facultative arrested development represents such an adaptation which, by facilitating persistence of the larval forms for prolonged periods in the host, enables the parasite to capitalize on optimal opportunities for transfer. The phenomenon appears to be widespread among parasitic organisms and it has been particularly well studied in the parasitic nematodes of domestic animals (Gibbs, 1986).

The term hypobiosis, which literally means a slowing down of life processes, may be defined as a temporary halt in the parasitic phase of development at a specific point in the nematode life cycle, was first suggested by Gordon (1973) to include such terms as arrested, retarded, inhibited, or suppressed development when these are applied to worms that have not completed their development in the host within the commonly accepted development interval for the species. Arrested development is an important feature of the life cycles of a number of nematode species. It is of particular importance in the order Strongylida especially the *Trichostrongyles* of grazing ruminants, the small strongyles of horses and the hookworms of dogs and humans.

Gastro-intestinal nematodes can survive harsh conditions by hypobiosis or arrested development of larvae (usually L₃ or early L₄) within the host. The humid tropical climate is favourable for the survival, development and transmission of gastro-intestinal nematodes throughout the year (Chiejina *et al.*, 1988).

Under normal circumstances when a host is infected with a nematode, parasitic development begins immediately and continues through to adult males and females in the normal prepatent period characteristic of the species. However, under certain circumstances larval development will be halted or arrested at a specific stage (usually L₃ or L₄) and the prepatent period is prolonged sometimes for weeks or months.

Arrested larvae not only fail to grow but also their metabolic rate decreases significantly and they stop moving. In this state they can survive for weeks or months before resuming development and may also be resistant to some anthelmintics at doses that are usually lethal to adults and normally developing larval populations

2.5.3 Types of hypobiosis

Horak (1981) suggested that there are basically two types of arrested development in parasitic nematodes which he termed non-specific and seasonal arrested development. Non-specific arrest could occur at any time and its causes could either be host-related or parasite-related factors which affect the immediate environment of the nematode, causing inhibition in development.

Seasonally arrested development, on the other hand, represents an annual event during the same season and is dependent upon nematodes being adapted to a particular environment and being responsive to external environmental stimuli acting upon the infective larvae which result in arrest at a later stage of development. However, this phenomenon is not exclusive to the parasitic nematodes. A strictly analogous

modification of development has been described with some of the free-living nematodes, in particular *Caenorhabditis elegans*. In this species a type of hypobiotic larva is produced in response to an unfavourable stimulus in the environment of the free-living nematode (Gibbs, 1986).

2.5.4 Initiating factors in arrested development

Epidemiological and experimental evidence has identified three factors responsible for the initiation of arrested development (Michel, 1976; Armour, 1980; Armour, 1982; Gibbs, 1986).

These factors include: Seasonal influences on infective larvae on pasture, host immune responses inhibiting the normal development of the parasitic phase of the life cycle and an overcrowding effect whereby the presence of adult worms causes the "feedback" inhibition of incoming infective larvae which go into arrest until the adult worm population decreases in number or is eliminated.

2.5.5 Seasonal Arrest (Hypobiosis)

Hypobiosis is the term most often used for arrested development that has a seasonal basis. It is a biologically important feature since it seems to be of particular importance in nematodes with relatively short adult life spans. In these species, hypobiosis is initiated by an environmental signal received by free-living L₃. When these L₃ subsequently infect a host, they do not develop continuously through to adults but instead, are arrested in host tissues either as exsheathed L₃ or as early L₄ larvae (Michel *et al.*, 1975; Ogunsusi and Eysker, 1979; Chiejina *et al.*, 1988; El-Azazy, 1995; Eysker, 1997). This suspension of development helps some nematode parasites to survive the dry seasons. Resumption of development usually coincides with the onset of the rainy seasons, the most favourable period for larval development and transmission on pasture

(Agyei *et al.*, 1991; El-Azazy, 1995; Tembely, 1998). The stimuli for the onset of arrested development in tropical areas, which are linked to the dry conditions, are in contrast to those stimuli (e.g. falling temperatures) for nematode parasites of ruminant livestock found in temperate zones (Levine, 1978; Allonby and Urquhart, 1975; Vercruyssen, 1985; Chiejina *et al.*, 1988; El-Azazy, 1995).

Gatongi *et al.*, (1998), conducted a study in a semi-arid area of Kenya and reported higher proportion of hypobiotic larvae recovered during the dry season of a year, indicating that hypobiosis was an important phenomenon in the survival of *Haemonchus contortus* during drier months as over 90% of *H. contortus* in the abomasal contents with only 10% found in mucosal digest in both sheep and goats. Similar results were reported by Eysker and Kooyman (1993) and Jacquier *et al.*, (1995).

In Nigerian Derived Savannah, seasonal changes and hypobiosis in *H. contortus* infection indicated greater gastro-intestinal nematode infection rates during the rainy season rather than the dry season (Fakae, 1990b).

Some studies suggested that hypobiosis of *H. contortus* in the Tropical and sub-Tropical regions of the world are very limited or have variable results. For example no hypobiosis was detected in Egypt (El-Azazy, 1990), where as low levels of hypobiosis were observed in Zimbabwe (Pandey, 1990) and Eastern Nigeria (Chiejina *et al.*, 1988). High levels of hypobiosis were reported in Northern Nigeria (Van Geldorp and Schillhorn Van veen, 1976; Ogunsusi and Eysker, 1979). It appears that seasonal hypobiosis is an important option for the life cycles of a number of nematodes of grazing animals, particularly ruminants. This is particularly true of the Trichostrongyles such as *Ostertagia*, *Haemonchus*, *Trichostrongylus*, *Cooperia* and *Dictyocaulus* spp as well as *Oesophagostomum* spp and also, the small strongyles of horses (Colin, 1998).

2.5.6 Immune Arrest

Another form of arrested development is also recognized and is due to the influence of immune response. As animals graze, they continually ingest infective third stage larvae which develop to adults in the normal prepatent period. As the grazing season progresses these animals develop a strong immune response to nematode infections and one of the manifestations of the immune response is the inhibition of larvae inside the host. Larvae infecting a host are more likely to undergo arrest if there is already an established population of adult worms in that host. In sheep, goats and pigs maturation of these immunologically arrested larvae appears to be linked with parturition. An inhibition of the immune response, specifically associated with gut-dwelling nematodes, is related to serum levels of prolactin. Immune competence is restored when prolactin levels drop, at weaning, and worm burdens are usually expelled as a consequence of the restored immune response (Gibbs, 1986; Colin, 1998).

2.5.7 Quiescence

Hypobiosis and immunological arrest of parasitic larvae should be distinguished from other forms of developmental arrest seen in paratenic and intermediate hosts during the life cycles of many nematodes, particularly the ascarids and spirurids. This form of arrested development is often called quiescence since it is an intrinsic part of the life cycle, is not an option and is not triggered by extraneous influences (Colin 1998).

2.5.8 Significance of hypobiosis in the biology of nematodes

The significance of arrested development to the parasitic nematode has been the subject of much speculation. Whatever the triggering mechanisms are that initiate developmental arrest and induce resumption of development, the phenomenon has considerable biological importance to nematodes that incorporate it into their life cycle

options. It also has considerable epidemiological implications to nematode hosts and must be considered when devising methods for prevention and control of nematode infections and disease. There are several reasons why arrested development is important (Brunsdon, 1980; Gibbs, 1986; Colin, 1998) and they include:

Firstly, Arrested development ensures survival of nematodes during times when conditions are hostile to their survival in the external environment. Secondly, the development of adults from arrested larvae will produce significant contamination of pastures with nematode eggs at a time when environmental conditions are, once again, favourable for development of pre-parasitic stages to infective larvae. This contamination which begins at the start of the grazing season and reaches a peak several weeks later is particularly dangerous for young, immunologically naive animals grazing pastures for the first time and lastly, hypobiotic larvae are depressed metabolically and hence may be less susceptible to some anthelmintics. Clearly the choice of drugs to be used in a nematode control program will be influenced by the role of arrested development in specific nematode life cycles and by the susceptibility of arrested larvae to the range of available anthelmintics.

2.6 Clinical and Pathological Features of Helminth infections

2.6.1 Parasitic gastro-enteritis

The major parasites associated with parasitic gastro-enteritis in small ruminants in sub-Saharan Africa are *Haemonchus contortus*, *Trichostrongylus colubriformis*, *Oesophagostomum columbianum*. Other nematodes of lesser importance are *Trichostrongylus axei*, *Bunostomum trigonocephalum*, *Trichuris ovis*, *Cooperia* spp and *Strongyloides papillosus*. *Ostertagia ostertagi* and *Nematodirus fillicolis* are important in cooler highland areas (Lughano and Dominic, 1996).

Parasitic gastro-enteritis is widely distributed in Nigeria, the prevalence and seasonal changes in the abundance of the causative parasites have been studied and reported from some geographical zones of the country (Chiejina, 1986; Nwosu *et al.*, 1996a, b). Gastrointestinal nematodes differs in their predilection sites and their additive pathogenic effects result in the differing clinical and pathological features of parasitic gastro-enteritis complex.

2.6.1.1 *Haemonchosis*

Haemonchosis caused by *Haemonchus contortus* a predominant, highly pathogenic and economically important parasitic disease of sheep and goats in Africa (Mortensen *et al.*, 2003). The pathogenesis of haemonchosis is related to the blood sucking habit of the parasite. It has been estimated that each worm sucks about 0.05 ml of blood per day by ingestion or seepage from lesions (Urquhart *et al.*, 2000).

Perry *et al.*, (2002), identified haemonchosis as one of the top ten constraints to sheep and goats rearing in East Africa. Studies carried out by Molalegne *et al.*, (2011) in Ethiopia showed infection of sheep and goats by *Haemonchus* with prevalence of 75.9% and 55.9% respectively indicating that haemonchosis undoubtedly has an impact on the health and productivity of these animals.

In addition, studies conducted by Ajanusi and Chiezey (2005), in Zaria, Nigeria, showed the prevalence of *Haemonchus contortus* in goats to be 89.1%. The mean PCV of infected goats were negatively correlated with worm burdens, showing that *Haemonchus contortus* was responsible for the low PCV in animals with high worm burdens. Ebbo *et al.*, (2003) and Useh (2005) reported a high incidence (60%) of gastrointestinal parasitism in small ruminants presented for clinical examination at the Usman Danfodio University Veterinary Teaching Hospital (VTH), Sokoto, and ABU

VTH Zaria, respectively. On the basis of clinical signs, haemonchosis may be divided into three syndromes; hyperacute, acute and chronic haemonchosis in goats and sheep.

Hyperacute haemonchosis: Occurs when there is a sudden massive challenge of susceptible animals with infective larvae resulting in severe blood loss due to haemorrhagic gastritis. It often a challenge to young animals in their first grazing period. The syndrome is of short duration and is characterised by sudden death although in some animals, dark-coloured faeces may be seen before death. Faecal egg counts of up to 400,000/g may be countered in the affected animals. However, hyperacute haemonchosis is not very common in field infection (Taylor *et al.*, 1990).

Acute haemonchosis: Occurs when animals are exposed to a continuous larval challenge leading to gastritis associated with hypoproteinemia and generalised sub-mandibular oedema called “bottle jaw”. Other signs include weakness, pallor of the mucous membrane, lethargy or agalactia which may lead to starvation and death of kids. Dark-coloured faeces are often observed. Self-cure may occur at any stage of the disease. The syndrome is more common when young susceptible animals become infected (Ukoli, 1984; Taylor *et al.*, 1990).

Acute haemonchosis is characterised by a pale and watery carcass. The abomasal mucosa is petechiated and oedematous with many parasites on its surface and contents. There is a marked expansion of the bone marrow throughout the medullary cavity which may extend up to the epiphyses (Lughano and Dominic, 1996).

Chronic haemonchosis: Is the common form of field infection. The syndrome is caused by gradual intake of infective larvae and the course of disease may take 2- 6 weeks. It is a chronic gastritis with chronic blood loss, rough hair coat and stunted growth. Chronic

haemonchosis is aggravated and often confused with malnutrition (Soulsby, 1986; Lughano and Dominic, 1996).

At necropsy, chronic haemonchosis is characterised by pallor of carcass, hyperplastic thickening of the abomasal wall, chronic expansion of the bone marrow and resorption of the cancellous and cortical bones. In terminal stages the bone marrow reverts to white due to exhaustion (Ndamukong, 1987). The clinical pathology of haemonchosis includes lowered PCV, haemoglobin concentration, erythrocyte counts and serum iron (Soulsby, 1986)

2.6.1.2 Trichostrongylosis

Trichostrongylosis is commonly a disease of young animals. The penetration of larvae and adult worms into the intestinal mucosa results in desquamation of the latter causing a malabsorption syndrome and hence a protein-losing gastro-enteropathy and hypoalbuminemia. Heavy infections cause acute enteritis which is characterised by dark-coloured diarrhoea and foul smelling faeces. There may be sudden death without evidence of anaemia or emaciation but weakness of the legs is a frequent feature. Most commonly, trichostrongylosis is a chronic wasting disease characterised by loss of appetite, emaciation, loss of weight, dry skin, diarrhoea, oedema and atrophy of skeletal muscles or myocardium (Lughano and Dominic, 1996).

At necropsy, the acute disease is characterised by a swollen and haemorrhagic or catarrhal intestinal mucosa and, worms may be found in the mucosal scrapings. The chronic disease is characterised by an emaciated carcass, fatty degeneration and, a thickened, inflamed and ulcerated intestinal mucosa (Ndamukong, 1987; Lughano and Dominic, 1996).

Histopathologically, chronic infection with *T. colubriformis* is characterised by marked villous atrophy, flattening of the intestinal mucosa and osteoporosis. The clinical pathology is characterised by hypoalbuminaemia, hyperglobulinaemia and hypophosphataemia (Lughano and Dominic, 1996).

2.6.1.3 Oesophagostomosis

The pathogenicity of *Oesophagostomum columbianum* is related to the migration of larvae in muscularis mucosa of the large intestine resulting in a fibroblastic response around the larvae forming fibrous nodules. The extensive nodular formation interferes with digestion, absorption and bowel movement. Mucoïd diarrhoea or sometimes constipation, emaciation, general weakness, dry skin, prostration and death are the common clinical features. The diarrhoea often coincides with the emergence of larvae from the nodules. The nodules are frequently invaded with pyogenic bacteria which cause suppuration. Rupture of the nodules may cause peritonitis and multiple adhesions (Lughano and Dominic, 1996).

At post mortem examination, the most severe form of the disease is characterised by ulcerative colitis. The adult worms cause thickening of the bowel wall, congestion and production of excessive amount of mucus. In primary infection, adult worms are found in the lumen of the large intestine where they are often covered with mucus and there may be few nodules. In super-infection, there is an extensive nodular formation with marked emaciation and severe fatty degeneration. Abscesses with greenish or yellowish pus may also be present (Reid, 1973; Lughano and Dominic, 1996).

2.7 Diagnosis of Helminth Infections in Small Ruminants

The diagnosis of helminth parasites of small ruminants is based on demonstrating the presence of helminth eggs, or larvae, in faecal samples, or the presence of parasites

recovered from the digestive tracts or other viscera of the animals. Although a great variety of methods and modifications have been described for such diagnosis, standardization of techniques, such as egg or larval counts, worm counts, pasture larval counts, etc., does not exist. Therefore, in practice, most diagnostic laboratories as well as teaching and research establishments apply their own protocols of test procedures (Kassai, 1999). The following diagnostic procedures for helminth infections of small ruminants are relevant to African conditions.

2.7.1 Blood test

Blood tests may reveal anaemia (low blood haemoglobin, PCV and red blood cell count), elevated blood pepsinogen and hypoalbuminaemia, which would lead to a presumptive diagnosis as no other nematode of sheep/goat is blood-sucking to that degree.

2.7.2 Faecal egg counting

This is the most common antemortem means of diagnosis of helminthosis and is based on the assumption that the size of worm burden in animals may be accurately deduced from faecal egg counts. Faecal egg counting is a cheap and easily performed technique. The McMaster technique is a rapid, easy and most commonly used method in quantitative analysis of nematode eggs counts in the field and in epidemiological surveys. However, the number of nematode eggs or larvae in faeces is influenced by several factors such as the biotic potential of the nematode species, resistance of the host, developmental stage of the parasite, season of the year, quantity and consistency of the faeces passed and sensitivity of the diagnostic method used. Therefore, the interpretation of faecal egg counts should take into account these factors (Pomroy, 1996b; McKenna, 1996; FECPAK, 2001b).

2.7.3 Faecal culture

Faecal culture methods are the most common routine means for the diagnose helminthosis in small ruminants. The strongylid nematode genera produce eggs that are similar in appearance and cannot be easily discriminated. To identify nematodes in faecal samples, faecal cultures are required to yield L₃, which generally can be differentiated to genus level (Anon, 1986; Hansen and Perry, 1994; Urquhart *et al.*, 1996; Kassai, 1999; Van Wyk *et al.*, 2004). *Nematodirus*, *Strongyloides* and *Trichuris* spp have eggs that can be differentiated by their distinct morphological features.

2.7.4 Post-mortem worm counting

Post-mortem examinations and identification of adult worms and arrested larvae (L₄) in animals are the definitive means of identifying the helminth parasites infecting an animal. This is considered to be the most accurate method of diagnosis of helminthosis, however, it is also expensive. Similar to faecal egg counts, there are many procedures that are described for post-mortem examination for nematode parasites (Anon, 1986; Hansen and Perry, 1994; Pomroy, 1995a; Urquhart *et al.*, 1996; Kassai, 1999).

2.7.5 FAMACHA eye-colour scores

In areas where haematophagous (blood-sucking) worm species, particularly *H. contortus*, are prevalent, estimation of clinical anaemia by examining ocularmucous membranes of sheep and goats using the FAMACHA© chart (Bath *et al.*,1996) is becoming a common diagnostic procedure. This procedure of estimationof clinical anaemia can give a relatively reliable approximation of thehaematological status of sheep and goats suffering from the haematophagousworm infections, especially at lower haematocrit values (Van Wyk and Bath, 2002).

2.7.6 Other Methods

Other methods used in the diagnosis of helminth infections include immunodiagnosis and enzyme assays. However, these methods are used where laboratory facilities are adequate and are of limited use in direct field investigation of helminthoses (Lughano and Dominic, 1996)

2.8 Anthelmintics

Anthelmintics are drugs that either kill egg laying adults, or kill larvae before they become adults and become capable of laying eggs (Rook, 2010). While some anthelmintics are effective in killing *Haemonchus contortus*, there are two major problems that arise when using anthelmintics. The first problem that affects mainly sheep and goat producers is that there are very few anthelmintics that are actually approved by the FDA for use in small ruminants. The second problem is the resistance that parasites have developed to many anthelmintics. Resistance occurs when a drug is overused and the parasites develop a tolerance to the drug, making it no longer effective in killing them (Terrill *et al.*, 2001).

Resistance makes it very difficult to effectively control *Haemonchus contortus* because it lowers the number of options available to treat the parasite, especially since resistance to one drug often means that a parasite will be resistant to all drugs in that compound class (Leathwee and Switherland, 2002; Merial, 2003).

Anthelmintics are divided into **broad spectrum** - i.e. those able to kill a wide variety of parasites and **narrow spectrum** - those only able to kill one or two types of parasites (Small and Parkes, 2010).

There are four different types of broad spectrum drenches, each with a different mode of action:

2.8.1 Benzimidazoles (BZ)

These are also known as white drenches. Benzimidazoles contain the anthelmintics albendazole, fenbendazole, mebendazole, oxfendazole, and oxibendazole. These chemicals are effective against all gastrointestinal nematodes and adult tapeworms. The drugs are deposited in the rumen and are slowly released into the gastrointestinal tract. They act on the intestinal cells of the nematode and the skin cells of the tapeworms, inhibiting uptake of glucose and causing starvation. They kill not only the adult forms but also the immature stages. They are also ovicidal – with activity against eggs being passed by the nematodes and tapeworms (Terrill *et al.*, 2001).

Currently, fenbendazole is the chemical most commonly used from this group for sheep/goats (Safeguard 10% suspension, Intervet Schering-Plough Animal Health) followed by albendazole (Valbazen, Pfizer Animal Health). While benzimidazoles have a high margin of safety (meaning that it can safely be given at double or triple the labeled dose) and are effective against many species of intestinal parasites, their efficacy against *Haemonchus contortus* is fairly low. The other problem with benzimidazoles, which is more pronounced in this class of drugs than in others, is that if a parasite is resistant to one of the benzimidazoles, the resistance is most likely spread among all of the drugs in this class. Albendazole also has activity against adult flukes, but should not be used during breeding or the first trimester of pregnancy because of toxicity to the foetus in early gestation. Generally, however, the benzimidazoles class of drugs are very safe with low levels of toxicity. The dose used in sheep is the same as the cattle dose but goats metabolize the drug quickly and require the dose to be doubled (Rook, 2010).

2.8.2 Imidazothiazoles (LV) and Tetrahydropyrimidines

This group contains levamisole, pyrantel and morantel. The most important drug for sheep and goats in this class is levamisole. Levamisole is approved for use in sheep and is also shown to be very effective against *Haemonchus contortus*. They are also known as yellow drenches. It is also used as an immunomodulator in humans and for the treatment of specific types of cancer. It is not ovicidal and the difference between animal toxicity and efficacy is very narrow making overdose and poisoning a potential issue. Prior to this drug not becoming available, the most commonly reported adverse drug reaction in goats and sheep was from the use of levamisole.

Levamisole works by paralysing the parasite so that it is removed rapidly from the gut. It works well against a broad range of adult worms but less so against the immature stages (e.g. L4). However, it is particularly effective against lungworm. Signs of toxicity in animals include salivation, slow heart rate and muscle tremors with occasional death. Morantel can be used to treat GIN but is not effective against the immature forms. Pyrantel is rarely used in livestock (Terrill *et al.*, 2001).

2.8.3 Macrocyclic Lactones (ML)

This group contains the avermectins (ivermectin, doramectin, eprinomectin) and the milbemyctins (moxidectin). These compounds are derived from specific species of the *Streptomyces* genus and all act similarly. MLs have activity against most nematodes including the L4 stage, but not tapeworms or flukes. Ivermectin and moxidectin are effective against *Haemonchus contortus* in normal situations, but they are only approved by the FDA for use in sheep, and requires extra-label use in goats. Extra-label use requires that the producer work with a veterinarian to get a prescription for the desired drug, as well as the proper doses and withdrawal times when using the

anthelmintics. Sheep should be given the sheep drench form of ivermectin and moxidectin, and goats should receive a higher dose. They are not ovicidal. They also have activity against some arthropod ectoparasites, specifically sucking lice and nose bots (*Oestrus ovis*), as well as some activity against keds (*Melophagus ovinus*) and mange (Chorioptes, Sarcoptes and Psoroptes). Because of this spectrum of activity, drugs in this class are sometimes called endectocides (Kaplan and Ray, 2004; Terrill *et al.*, 2001).

When administered, the drugs are stored in fat tissue and then slowly released into the body. These pharmacokinetic properties result in long meat and milk withdrawal times (Ivomec, Merial = 15 days meat withdrawal for sheep drench and 35 days for injectable). Moxidectin however, is the only drug in this class which is considered to have significant prolonged activity - approximately 35 days when administered as an injection, and 21 days when administered as a drench, against *Teladorsagia* and *Haemonchus contortus*. The mode of activity is believed to be largely against neurotransmitter receptors specific to invertebrates. But they are considered quite safe for mammals (Terrill *et al.*, 2001).

2.8.4 Amino-acetonitrile derivatives (AAD)

The first product from this new class of drugs (monepantel) was released March 31, 2009 in New Zealand and the UK (Zolvix, Novartis Animal Health). This is the first new class of anthelmintics developed in 25 years and appears to have excellent activity against resistant strains of GIN as well as immature forms of nematodes, and in particular *Haemonchus*. The drug is also of low toxicity as it targets a unique, nematode-specific class of acetylcholine receptor subunits (Terrill *et al.*, 2001).

2.8.5 Narrow-spectrum drugs

They are designed to target particular types of worms and are generally only effective against one or two worm species. They include closantel and praziquantel which are narrow-spectrum drench with action against susceptible *Haemonchus*. No closantel products are registered for use in goats (Terrill *et al.*, 2001).

2.8.5.1 Closantel

This drug is effective only against internal parasites that suck blood. In sheep and goats, this will include *Haemonchus contortus* (including larval stages) and the liver fluke *Fasciola hepatica*. It also has persistent activity by binding to the host's plasma proteins.

2.8.5.2 Praziquantel

This drug acts against the adult and immature stages of tapeworms and is of most use for control of tapeworms in guardian and working dogs (Scarfe and David, 2012).

2.8.6 Route of administration

Administration of Anthelmintic

Anthelmintics can be administered to animals by varying means, with the most common being in the form of oral drenches. Oral drenches are thick liquid suspensions of the anthelmintics that are deposited into the back of the animal's mouth (Terrill *et al.*, 2001). Some anthelmintics are available in the injectable form, but these are not generally recommended for use in small ruminants. It is particularly important when using drugs not labeled for use in sheep and goats that the concentration of the active substance be considered when determining the appropriate dose for the animals. It is also necessary to realize that sheep and goats metabolize many anthelmintics at

different rates, with goats usually metabolizing the drugs faster and often requiring a larger dose.

When using products that are not approved for sheep and goats, it is imperative that the amount being given is in fact the recommended dose for sheep or goats, not the species for which the formula is marketed. Some products may be marketed for cattle as injectable or pour on, but will be ineffective if administered to sheep or goats in this manner. Pour-on anthelmintics are formulated to be absorbed through the skin of cattle, but do not absorb in therapeutic amounts through sheep and goat skin due to the wool and hair of these species. It is also important that drenches are mixed in the proper way and administered while they are still effective. If drenches are not mixed properly, they may settle out, and the animal will not receive the effective amount of the anthelmintics. It should also be common practice to check the expiration date of a product before administration (Terrill *et al.*, 2001).

2.8.7 Anthelmintic Treatment Schemes

The control of GIN-infections is largely based on preventive or therapeutic use of anthelmintic drugs (Williams, 1997). On most farms the flocks are traditionally treated two or more times per year, without coprological checking for the necessity of treatment or its efficacy afterwards. Mostly, these strategic treatments are performed in spring at the beginning of the grazing period to prevent the contamination of the pasture and at the end of summer, when infestation of the pasture with larvae and of the animals with adult worms usually is high ()

Additional treatments are administered whenever clinical signs become obvious. Pasture management specifically aiming at worm control includes clean-grazing systems (Rutter *et al.*, 1984) and dose-and-move strategies (Michel, 1985; Coles *et al.*,

1992; Barger 1997). Unfortunately, most farmers have only limited pastures available and cannot perform rotational grazing with adequate resting intervals. In consequence, in heavy infected flocks some farmers have to treat their animals up to 6 times a year in order to prevent severe production losses and mortalities. However, these pasture management strategies rely on efficacious anthelmintics (Boa *et al.*, 2001). When treatment is not fully efficacious only unsusceptible worms survive, produce eggs giving rise to resistant worms, which re-infect the flock and a further selection for anthelmintic resistance is the result.

2.9 Anthelmintic Resistance

The definition of resistance according to Prichard *et al.* (1980) is as follows: “Resistance is present when there is a greater frequency of individuals within a population able to tolerate doses of a compound than in a normal population of the same species and is heritable”.

This early definition still adequately describes the nature of resistance and hence was repeatedly reformulated and further extended to more molecular and genomic approaches (Gilleard, 2006).

Wood and Bishop (1981) classified four factors, which influence the rate at which resistance to a pesticide develops and spreads in a population:

Firstly; Genetic, including mutation rate and relative dominance of the trait, secondly; Reproductive, including generations per year and fluctuations in population size; thirdly; Behavioural/ecological, including migration of the pest species and its ability to avoid the pesticide and fourthly; Operational, including the proportion of the population exposed and the persistence of the chemical control agent.

Regarding the development of anthelmintic resistance in GINs, factors (1), (2) and (4) are very important and therefore have been studied thoroughly.

A repeated treatment of gastrointestinal nematode populations with the same anthelmintics selects individuals that have innate or acquired resistance to the drugs. Resistance is inheritable by transmission of resistant alleles. Even point mutations can change the structure of proteins what may lead to a decrease of susceptibility to a pharmaceutical compound (Tiwari *et al.*, 2006; Walsh *et al.*, 2006; Prichard and Roulet, 2007). This can enable the resistant proportion of the parasite population to survive treatment. Treatment becomes ineffective when the proportion of resistant genes increases and thereby dilutes the susceptible genes (Sangster, 1999).

Anthelmintic resistance (AR) is likely to develop wherever the same substances are too frequently used. Treatments with less than the recommended dose rate may accelerate the development of AR (Chartier *et al.*, 2000; Chartier *et al.*, 2001). Furthermore, side resistance to other compounds in the same chemical group with a similar mode of action may occur. E.g. if the parasite is resistant to fenbendazole, then it is also resistant to albendazole. This is less true with the avermectins and moxidectin, where moxidectin may still be effective in the face of avermectin resistance, but often not for long (Fleming *et al.*, 2006).

Since the definition of anthelmintic resistance by Prichard *et al.* 1980, anthelmintic resistance has become a major and still increasing problem in animal husbandry worldwide, especially in small ruminant livestock (Waller, 1994; Waller, 1997; Wolstenholme *et al.*, 2004). All three current broad-spectrum anthelmintic families – the benzimidazoles, imidazothiazoles and macrocyclic lactones – are concerned. The prevalence is high especially in Australia and North America, but also in Europe reports

of anthelmintic resistance in small ruminants are increasing (Bauer *et al.*, 1987; Bauer, 1988; Bauer *et al.*, 1988; Bauer, 2001; Hertzberg and Bauer, 2000; Schnyder *et al.*, 2005; Artho *et al.*, 2007; Cringoli *et al.*, 2007). Particularly in large flocks with industrial production schemes and high stocking rates, which practise frequent treatment schemes, parasite populations tend to quickly lose the sensitivity to administered drugs (Borgsteede *et al.*, 1997; Chartier and Hoste, 1994; Chartier *et al.*, 2001).

2.9.1 Refugia

Sustainable worm control strategies are largely based on the idea that a proportion of worms are not exposed to anthelmintics, i.e. survives “in refugia”. Such worm populations are a source of reinfection and thus ensure that resistant worms do not become a dominant part of the total population (Boa *et al.*, 2001; Pomroy, 2006; Waghorn *et al.*, 2008). Usually, developmental stages of gastrointestinal nematode in the environment, i.e. eggs and free-living larvae on infected pastures constitute the main part of the refugia. By means of TST this proportion can be reinforced with parasites in untreated animals. Refugia, defined by Van Wyk, (2001) as the proportion of a parasite population that is not selected by drug treatment, is now considered to be probably the most important factor in delaying the development of anthelmintic resistance. Van Wyk, (2001) and Coles, (2002) hold the view that there should always be some animals left untreated. Thereby, also susceptible worm strains may survive in the flock and the population of resistant worms can be diluted. The higher the proportion of the GIN population is on the pasture, the slower the selection for resistance (Sangster, 2001). Above that, Sissay *et al.*, (2006) and Leathwick *et al.*, (2008) showed that through exploitation of refugia – i.e. by allowing flocks graze on pastures infected with susceptible worms or by introducing bearers of susceptible strains in the flock, anthelmintic efficacy can be restored.

Van Wyk *et al.*, 2002 also hold the view that to minimize the development of anthelmintic resistance, the proportion of the population under drug selection is the single most important factor influencing how rapidly resistance will develop. Therefore, nematode control programs should be designed to maintain the maximum amount of refugia (portion of the population not exposed to the drug) that is consistent with acceptable parasite control (Van Wyk, 2001). Maintaining a large refugium causes resistance to develop at a much slower rate because worms in refugia provide a pool of genes that are sensitive to anthelmintics, which dilute the frequency of resistant alleles in the population and reduce the chances of worms carrying resistant alleles from mating with other resistant worms. Such a program will permit efficient production to continue, but will considerably reduce the rate of evolution for resistance, reduce drug residues in animal products and thus preserve the efficacy of the few remaining anthelmintics that are required for life-saving intervention (Van Wyk, 2001).

In order to accomplish the goal of maximizing refugia, it is necessary to leave a portion of the herd or flock untreated. Studies on host–parasite dynamics consistently find that parasite burdens are aggregated in groups of animals (Crofton, 1971) with a minority of animals harboring the majority of the parasites (Galvani, 2003; Sreter *et al.*, 1994). In sheep and goats it is common for 20–30% of the animals to harbor 70–80% of the worms. Therefore, a selective approach that targets the portion of the herd or flock with high worm burdens will successfully control parasites in the entire group, while also reducing drug costs and delaying the development of anthelmintic resistance (Barger, 1985).

Further investigations are necessary to identify the most appropriate indices for different situations and environmental conditions; so that the refugia effect is maximised for the

least risk of disease and production loss and development of anthelmintic resistance will be delayed or slowed down.

2.9.2 Detection of anthelmintic resistance

Anthelmintic resistance (AR) in livestock is usually suspected, if the clinical condition of an animal does not improve after anthelmintic treatment. Often, this is due to factors like under dosing, faulty drenching equipment or application, and inaccurate assessment of the body weight. These factors have to be taken into account first, before considering an AR.

Various AR detection approaches are under discussion. Not every assay is suitable for detection of all anthelmintic classes. A variety of in-vitro assays – like the egg hatch assay and larval motility tests – have been developed, in which the parasite stages are directly incubated in the chemical compound (Taylor *et al.*, 2002). The egg hatch assay (Le Jambre, 1976), was used for BZ's and levamisole, but is unsuitable for the detection of resistance against avermectins and closantel. The incubation of the eggs in the drugs inhibits the hatching of the larvae and therefore further development. The larval motility tests are useful for detecting BZ and ML resistance. The larvae are incubated in the drugs and then motility of the larvae is measured by electronic detectors (Folz *et al.*, 1987), by migration through a sieve (Sangster *et al.*, 1988) or by observation (Gill *et al.*, 1991). However, none of these methods takes into consideration the bioavailability and efficacy of the drugs in the treated host animal.

The faecal egg count reduction test (FECRT) is the most efficient in-vivo assay, which can be used to evaluate the efficacy of drugs under field conditions (Taylor *et al.*, 2002).

2.9.3 Faecal Egg Count Reduction Test (FECRT)

The most widely used test for resistance detection and monitoring of GIN-infections is the FECRT, which is suitable for all anthelmintic classes. The FECRT estimates the degree of resistance by comparing the faecal egg counts (FEC) before and after treatment (Coles *et al.*, 2006)

To perform FECRT, a minimum of 30 lambs or young adults (first grazing season) with elevated faecal egg counts (individual minimum counts of 150 epg but 300 epg is preferred) is required.

Ten to 15 lambs are randomly assigned to control and treatment groups. It is necessary to use these many animals per group because of the normal variation in egg output between animals. If three anthelmintics are being evaluated (e.g. ivermectin representing the macrocyclic lactones (ML) and fenbendazole representing the benzimidazoles (BZ) and levamisole (LV)), then four groups (60 animals) are needed (e.g. control group (no treatment), ML group, BZ group and LV group). Individual faecal samples are obtained per rectum on day 0 (treatment day), lambs are weighed using a scale (to prevent underdosing) and treated appropriately by drenching. The controls are not treated but are sampled. All of the lambs are returned to the same pasture to graze. All the lambs are sampled again later (7 days for LV, 14 days for BZ and ML). The post-treatment faecal egg counts are compared to the control (Coles *et al.*, 1992).

The anthelmintic efficacy is determined by comparing faecal egg counts (FECs) before and after treatment (Boersema, 1983; Presidente, 1985).

The FECRT is now calculated according to the following formula (Bauer, 1986):

$FECR [\%] = (FEC \text{ before treatment} - FEC \text{ post treatment}) \times 100 / FEC \text{ before treatment}.$

An AR against an anthelmintic drug is considered present if the reduction after treatment is lower than 95% and the lower 95% confidence limit is below 90% (Coles *et al.*, 1992).

The World Association for the Advancement of Veterinary Parasitology (WAAVP) established the above guidelines which give precise details and recommendations for the use of this detection method (Coles *et al.*, 1992; Coles *et al.*, 2006). The FECRT provides a good estimation of AR with comparatively low costs and labour input (Taylor *et al.*, 2002; Cabaret and Berrag, 2004). Furthermore, this test allows to identify problems with the application of the anthelmintic under field conditions.

One limitation of this method is that the number of GIN eggs excreted usually does not correlate with the actual worm burden. There is no correlation between FECs and worm counts for *Trichostrongylus colubriformis*. Although Sangster *et al.*, (1979) reported a correlation between FECs and worm counts for *H. contortus*, no distinct proposition of the number of worms present in the host can be made by means of FECs.

In addition to the FECRT, it is advisable to identify the GIN species present after treatment by means of coprocultureS and L₃ determination. The GIN population is usually composed of several species. If only one species survives treatment, the anthelmintic treatment seems to have been efficacious against susceptible worms and thus, AR is present in all likelihood.

2.9.4 The FAMACHA©-method

The FAMACHA©-Method is a relatively simple and low-priced test that has been developed by scientists of the Onderstepoort Veterinary Institute in South Africa

especially for small, resource-poor farms (Malan *et al.*, 2001; Van Wyk and Bath, 2002). FAMACHA is an acronym derived from the name of the idea, Dr. Faffa Malan (FAffa Malan CHArt) a system evolved for the treatment and control of *H. contortus* in sheep and goats (Bath *et al.*, 1996). The system estimates levels of anaemia and blood loss and makes its practically easy for farmers to identify and potentially treat clinically sick or more susceptible members of a flock without the need to treat the entire herd as was previously the case. In Sub-Saharan Africa and in the Southern USA it has proved to be effective, provided that frequent inspection intervals are possible (Vatta *et al.*, 2002a, b, c; Van Wyk and Bath, 2002; Kaplan *et al.*, 2004; Burke *et al.*, 2007). All animals of the flock have to be inspected for signs of haemonchosis every two weeks in order to be able to act on time when anaemic pallor becomes obvious.

The technique is being increasingly used as part of integrated parasite control programmes in the Southern hemisphere. By examining and comparing the colour of the inside of the lower eyelid of a sheep or goat with a colour chart bearing pictures of sheep and goats conjunctivae classified into five categories ranging from the normal red through pink to practically white in severe anaemia, the degree of anaemia is estimated (Van Wyk and Bath, 2002). By doing so, it is possible to approximately assess the anaemia, which is often caused by blood sucking gastrointestinal parasites, such as *H. contortus*. The treatment can then be administered selectively to animals with a considerable degree of anaemia. The FAMACHA© method is therefore a practical tool for the accomplishment of Targeted Selective Treatments (TST), i.e. only animals showing clinical symptoms or reduced productivity should be treated with anthelmintic in order to slow down the development of AR (Mahieu *et al.*, 2007).

Unfortunately, so far only GIN-infections with a dominance of *H. contortus* can be monitored using the FAMACHA©-technique. Furthermore, it must be stated that other infections (liver flukes, Hookworm, blood parasites, conjunctivitis, any fever, etc.), environmental conditions (heat, drought and dust), stress and nutritional deficiencies can have influence on the colour of the eye's mucosa and thus may affect the FAMACHA©-scoring (Bath, 2000).

2.10 Strategies for Worm Management

In order to control GIN infections and at the same time conserve the efficacy of anthelmintic treatment, new strategies for worm management have to be developed and introduced in livestock.

2.10.1 Targeted Selective Treatment

Targeted Selective Treatment (TST) focuses on minimising the percentage of treated animals in a flock by directing individual treatments towards those animals most susceptible to disease or towards those animals that have been identified as highly infected and therefore are responsible for major pasture contamination (Van Wyk *et al.*, 2006). It is assumed that animals with high worm burden show symptoms such as diarrhoea, emaciation, anaemia and reduced productivity, whereas animals with low worm burdens do not. Using TST, only clinically suspicious animals are treated. The identification of suspicious animals has to be reliable and can be accomplished by means of coprological examinations (Fecal Egg Count), body condition scoring, body weight, milk yield and anaemic pallor, respectively (Van Wyk *et al.*, 2006).

Another approach to reduce the proportion of treated animals in a flock is the selective treatment of high-producing individuals. High-producing dairy animals and especially those in their first lactation period are often less resistant to GIN infections (Hoste and

Chartier, 1993; Chartier and Hoste, 1994). Therefore, the animals with the highest milk yield of the flock should be part of the treated proportion. If applied optimally, TST does not result in any significant production losses to farmers.

Since the amount of anthelmintics used is minimised, expenses for drugs can be reduced. As a further advantage of targeted selective treatment, a considerable percentage of the gastrointestinal nematode population in the flock will remain susceptible to treatment, by keeping it in refugia, i.e. not exposed to the drugs. As a consequence, the selection pressure for the development of anthelmintic resistance can be reduced.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Area

The study was carried out in 4 Local Government Areas in Kaduna state and include, NAPRI Shika, located at Giwa Local Government, on latitude 10° and 12° N and longitude 7° and 34° E, Farakwai located at Igabi Local Government, on latitude 10° and 49° N and longitude 7° and 34° , Kurmin Kaduna at Chikun Local Government, located on latitude 10° and 19° N and latitude 7° and 4° E and Damau in Ikara Local Government, located on 10° and 58° N and longitude 8° and 24° E.

3.2 Experimental Animals

The Red Sokoto and Sahelian breeds of goats were used for the study for a period of 1 year (August 2013 to July 2014). A total of 64 animals comprising of 16 each from the weaned and adult groups respectively were included from each breed for the FAMACHA study. There was equal distribution of male and females within each group. Hence 8 males and 8 females were allocated per group of adult or weaned goats. For the drug trials, a total of 700 animals from all study areas were used.

3.3 The Application of the FAMACHA[©]-Method

In this present study, the colour of the ocular conjunctiva was evaluated following the recommendations of the FAMACHA[©]-method (Van Wyk and Bath, 2002). The official FAMACHA[©]-anaemia guide was used (Plate 3.1). The guide shows 5 colour classes: 1 (red) and 2 (red–pink) being considered as non anaemic; 3 (pink) mildly anaemic; 4 (pink–white) anaemic and 5 (white) severely anaemic.



Plate 3.1:Official FAMACHA©-anaemia guide.

For FAMACHA© scoring, the lower eyelid of the animal is gently pulled down with the finger to expose the ventral conjunctiva. It can be helpful to push the upper eyelid down to cover the eyeball and the membrane nictitans. The colour of the lower conjunctiva is then evaluated by comparing it directly with the FAMACHA © chart (Plate 3.2).and then recorded



Plate 3.2:Application of the FAMACHA©-chart for the evaluation of the degree of anaemia on goats.

3.4 Determination of Packed Cell Volume (PCV)

Two millimeters of blood per animal was collected from the jugular vein twice in a month and then transported to the Department of Parasitology NAPRI, Ahmadu Bello University, Zaria. The collected EDTA-blood samples were used to define the Packed Cell Volume (PCV), of each of the animal by means of microhaematocrit centrifugation (Kraft and Dürr, 1999).

Briefly, after gently mixing the blood, a 75× 1.5 mm capillary tube was filled with blood up to $\frac{3}{4}$ of its length and one end sealed. The blood filled tubes were centrifuged at 12,000 rpm for 4 minutes using a microhaematocrit centrifuge. Finally, each tube was placed in a micro-haematocrit reader, to determine the percentage of packed red cell volume (PCV) for each animal (Kraft and Dürr, 1999).

3.5 The McMaster Faecal Egg Count Method

Faecal samples were collected directly from the rectum of all experimental animals using clean disposable polythene gloves, as described by Pratt, (1985) twice in a month for determination of faecal nematode egg count (FEC). The samples were transported to the Helminthology Laboratory, Department of Parasitology and Entomology and processed immediately. Faecal egg counts were determined using the modified McMaster technique with a saturated Sodium chloride/sucrose solution of specific gravity 1.18 as the flotation medium (Hansen and Perry, 1994). The nematodes eggs were identified to be strongylid eggs.

Briefly, two gram of the thoroughly mixed sample was weighed into a polythene tube. Five millimeter of water was added to the faeces and broken with the aid of a glass rod. The polythene tube was filled up with water, closed with the lid and shook very well. The sample was centrifuged at 1500 rpm for 3 minutes and the supernatant was

decanted. Six millimeter of the flotation medium was added, shook thoroughly to loosen the faeces and then centrifuged at 1500rpm for 3 minutes. The supernatant was collected into graduated polythene tube, this was done twice.

After centrifuging twice, the fluid volume of the supernatant was made up to 12 ml by adding more flotation medium. Well mixed aliquot of the supernatant of each sample was charged in both chambers of the McMaster slide and faecal egg count done at x10 objectives. The number of nematode eggs per gram of faeces was obtained by multiplying the total number of eggs counted in the two squares of the McMaster slide by the dilution factor of 20 (Hansen and Perry, 1994).

The multiplication factor of 20 was calculated as follows:

Number of eggs/g of faeces = x

Grams of faeces weighed = 2g

Total volume of saturated solution of Nacl/sucrose used=12 ml

Volume of the two McMaster slide wells=0.30 ml (0.15ml per well)

$$X = \frac{\text{total volume of Nacl/sucrose solution used}}{\text{Volume of the two McMaster slide wells} \times 2 \text{ g of faeces}}$$

$$X = \frac{12}{0.30 \times 2} = 12/0.6$$

$$X = 20$$

Therefore, Egg per gram= sum of the counts from the two wells x 20. Thus, the factor of 20 was multiplied with the total number of eggs counted in the two chambers to get

the number of egg per gram of faeces (Anon, 1977; Soulsby, 1982; Hansen and Perry, 1994).

3.6 Faecal Egg Count Reduction Test (FECRT)

Faecal samples, taken from the rectum of animals were analysed by the Faecal Egg Count Reduction Test (FECRT) according to Coles *et al.*, (2006). The FECRT provides an estimation of the anthelmintic efficacy by comparing faecal egg counts (FECs) before and after treatment (Boersema, 1983; Presidente, 1985).

Briefly 45 to 50 experimental animals were randomly assigned to 8 treatment groups. Anthelmintics including, Albendazole, levamisole and Ivermectin respectively were administered according to the manufacturers' instruction. Individual faecal samples were obtained per rectum on day 0 (treatment day), animals were weighed using a scale (to prevent under dosing) and treated appropriately by drenching and were returned to the same pasture to graze. All the animals were sampled again later (14 days for BZ, LV and ML). The post-treatment faecal egg counts were compared to the pre-treatment (Coles *et al.*, 1992).

The FECRT was calculated according to the following formula (Bauer, 1986):

$$\text{FEER} [\%] = (\text{FEC}_{\text{before treatment}} - \text{FEC}_{\text{post treatment}}) / \text{FEC}_{\text{before treatment}} \times 100.$$

Resistant against an anthelmintic drug is considered present if the reduction after treatment is lower than 95% and the lower 95% confidence limit is below 90% (Coles *et al.*, 1992).

3.7 Collection of Third-stage Larvae

To determine the species of the gastrointestinal nematodes, coprocultures were performed according to Roberts and O'Sullivan (1950). Therefore, pooled faecal

samples were mixed with sterile faeces/vermiculite and kept in small plastic containers for a minimum of 7 days at room temperature. The samples were kept humid, mixed occasionally and aerated every day for one hour. During this period the larvae hatched from the eggs and developed into L₃.

To collect the third-stage larvae the cultures were filled with lukewarm water and put upside down in a petri dish containing water close to a light source. After a period of 24 hours, the larvae would migrate towards the clear water and assembled in the reservoir of the petri dish.

The L₃ suspension was drained from the reservoir and filled in 300 ml beakers. The beakers were filled up with tap water and kept at 10° C for 12 h. After this sedimentation period, the supernatant was discarded and the cleaned larval suspension was filled into incubation flasks. These were kept at 4°C and was used for species identification using the keys of Bürger and Stoye, (1968) and Van Wyk *et al.*, (2004).

3.8 Determination of Body Weight

The body weight of the goat was measured in kilograms by following the procedure as described by Akpa *et al.*, (1998). The weight of the observer was taken first, and then the body weight of each of the animal was taken by carrying the goat individually and standing on a weighing scale. The differences between this weight and that of the observer gives the weight of the animal.

3.9 Data Analysis

Parameters were expressed as mean and their standard errors and results were presented in tables and charts. Data were analyzed using SPSS version 20 (2010). Student's t-test and Pearson correlation test were used to ascertain whether there was any association between EPG, PCV, FAMACHA eye scores and BW. $P < 0.05$ was considered as statistically significant.

The efficacy of anthelmintics was evaluated based on the reduction in faecal egg count and percentage of larvae found in the cultures. Calculation of the arithmetic mean, percentage of reduction and 95% upper and lower confidence limits were conducted according to the procedures described by Coles *et al.*, (1992). Resistance was declared when the percentage of reduction was less than 95% and the 95% lower confidence limit was less than 90%. If only one of the two criteria was met, resistance was suspected.

CHAPTER FOUR

4.0 RESULTS

Table 4.1 shows the Mean \pm SEM of Packed cell volume (PCV), egg per gram (EPG) and Body Weight (BW) of goats based on FAMACHA® eye score in a Research Institute. There is a statistical significant differences between goats with eye score 2 to 5. Goats with eye score value of 5 had the least values of PCV, BW and the highest value of EPG (13.86 ± 1.49 , 14.86 ± 1.53 and 9648.57 ± 2096.64) respectively. Whereas goats with eye score value of 2 had the highest value PCV, BW and the lowest value for EPG (28.71 ± 0.69 , 39.09 ± 12.52 and 20.44 ± 1.21) respectively,

Table 4.1: Mean \pm SEM of Packed Cell Volume (PCV) Egg per gram (EPG) and Body Weight (BW) of Goats based on FAMACHA© Eye Score at a Research Institute Zaria.

Parameters	FAMACHA© score				
	1(nonanaemic)	2(non-anaemic)	3(mildlyanaemic)	4 (anaemic)	5(severely anaemic)
PCV (%)	-	28.71 \pm 0.69a	27.30 \pm 0.43c	25.46 \pm 0.22d	13.86 \pm 1.49b
EPG (g)	-	39.09 \pm 12.52a	476.41 \pm 49.60c	859.56 \pm 107.83 d	9648.57 \pm 2096.64 b
BW (kg)	-	20.44 \pm 1.21c	19.66 \pm 0.32a	18.04 \pm 0.44b	14.86 \pm 1.53c

Pearson Correlations between PCV, FEC, BW and FAMACHA eye scores were all highly significant ($P < 0.001$) (Table 4.1.2). In particular, The FAMACHA eye score had a strong negative correlation with PCV and BW at Pearson Correlation coefficient of -0.117 and -0.017 respectively ($p < 0.0001$) which was highly significant. EPG had a strong negative correlation with PCV and a weak correlation with BW at a Pearson correlation of -0.109 and -0.114 respectively. Positive correlation were found, however, between FAMACHA eye score and EPG at Pearson correlation coefficient of 0.229 and between PCV and BW at Pearson correlation coefficient of 0.017 ($p < 0.0001$).

Table 4.1.2: Correlation values between FAMACHA® eye score (FAM), Packed Cell Volume (PCV), Egg per gram (EPG) and Body Weight (BW) of Goats examined at a Research Institute, Zaria.

PARAMETERS	CORRELATON VALUE
FAM VS EPG	0.229 ^{xxx}
PCV VS BW	0.017
FAM VS PCV	-0.117 ^{xxx}
FAM VS BW	-0.017 ^{xxx}
EPG VS PCV	-0.109 ^{xxx}
EPG VS BW	-0.114 ^x

*: $P \leq 0.05$; **: $P \leq 0.01$; *** $P \leq 0.0001$

FAM-FAMACHA, PCV-Paced cell volume, EPG- Egg per gram and BW-Body weight

The mean FAMACHA Eye Score during the entire duration of the experiment was influenced significantly by breed ($p < 0.05$). The mean FAMACHA Eye Score for the Red Sokoto was (3.30 ± 0.02) which was higher than the Sahelian goats (3.29 ± 0.02). (Table 4.1.3)

The mean PCV was significantly affected by breed ($P \leq 0.05$). The Red Sokoto had higher (27.52 ± 0.39) mean PCV than the Sahelian goats (25.77 ± 0.17). (Table 4.1.3)

Also the mean faecal egg counts was significantly affected by breed ($P \leq 0.05$). The Red Sokoto had higher (845.36 ± 94.95) mean EPG than the Sahelian goats (516.40 ± 68.17). (Table 4.1.3)

The mean weight was not significantly affected by breed ($P > 0.05$). The mean weight for the Red Sokoto was however higher than ($19.64 \pm 0.31\text{kg}$) that of Sahelian goat ($18.67 \pm 0.40\text{kg}$). (Table 4.1.3)

Table 4.1.3: Means \pm SEM of FAMACHA® Eye score (FAM), Packed Cell Volume (PCV), Egg per gram (EPG) and Body Weight (BW) by Breed of Goats examined at a Research Institute, Zaria.

PARAMETERS	BREED		P- VALUE
	RED SOKOTO	SAHELIAN	
FAM	3.28 \pm 0.02	3.29 \pm 0.02	0.834
PCV (%)	27.52 \pm 0.39 ^a	25.77 \pm 0.17 ^b	0.003
EPG (g)	845.36 \pm 94.95 ^a	516.40 \pm 68.17 ^b	0.005
BW (kg)	19.64 \pm 0.31	18.67 \pm 0.40	0.054

Means with different superscripts on the same row are significantly different ($P \leq 0.05$)

FAM-FAMACHA, PCV-Packed Cell Volume, EPG-Egg per gram and BW-Body Weight

The Mean \pm SEM of FAMACHA© Eye score (FAM), Packed cell volume (PCV), Egg per gram (EPG) and Body Weight (BW) by Sex of Goats examined at a Research Institute, Zaria is shown in Table 4.1.4

The mean FAMACHA© Eye score in goats was 3.27 ± 0.02 in the male and 3.30 ± 0.02 in female. The mean FAMACHA Score did not differ significantly ($P > 0.05$), even though the mean was higher in females than in males.

The mean PCV in goats was 26.16 ± 0.17 in the male and 27.13 ± 0.56 in female. The difference in the mean values was not statistically significant ($P > 0.05$), even though the mean was higher in females than in males.

The mean EPG in goats was 617.73 ± 84.83 in the male and 744.03 ± 80.88 in the female. The Mean values were not statistically significantly different ($P > 0.05$), even though the prevalence was higher in the female than in male. Considering sex as a risk factor, females were one and -half times more at risk of helminth infection (as judged by presence of egg in faeces) than males.

The mean BW in goat was 18.69 ± 0.36 in males and 19.61 ± 0.35 in females. The difference in the mean values was not statistically significant ($P > 0.05$).

Table 4.1.4: Means \pm SEM of FAMACHA® Eye score (FAM), Packed Cell Volume (PCV) Egg per gram (EPG) and Body Weight (BW) by Sex of Goats examined at a Research Institute, Zaria.

PARAMETERS	SEX		P- VALUE
	MALE	FEMALE	
FAM	3.27 \pm 0.02	3.30 \pm 0.02	0.402
PCV (%)	26.16 \pm 0.17	27.13 \pm 0.56	0.099
EPG (g)	617.73 \pm 84.83	744.03 \pm 80.88	0.281
BW (kg)	18.69 \pm 0.36	19.61 \pm 0.35	0.071

Means \pm SEM of FAMACHA[©] Eye score (FAM), Packed Cell Volume (PCV), Egg per gram (EPG) and Body Weight (BW) by Age of Goats examined at a Research Institute, Zaria are shown in Table 4.1.5

The value of the mean FAMACHA were significantly different ($P \leq 0.05$) with respect to age. The weaners had FAMACHA scores of 3.33 ± 0.02 and the adult had FAMACHA scores of 3.24 ± 0.02 .

The mean PCV by age of goats was 26.87 ± 0.55 in weaners and 26.43 ± 0.19 in the adult. The difference between the mean values was not statistically significant ($P > 0.05$).

The mean EPG by age of goat was significantly ($P > 0.05$) higher 798.59 ± 77.56 in weaned goats compared to adults goats with a mean EPG of 563.17 ± 87.69 . The prevalence was thus significantly higher in young small ruminants suggesting that they are more susceptible to parasitic infection compared to adult small ruminants.

The mean BW by age of goat was 12.76 ± 0.24 in weaners and 25.54 ± 0.26 in the adult. The difference between the mean values was statistically significant ($P < 0.05$). The adult goat had higher weight than the weaners

Table 4.1.5: Means \pm SEM of FAMACHA® Eye score (FAM), Packed Cell Volume (PCV) Egg per gram (EPG) and Body Weight (BW) by Age of Goats examined at a Research Institute, Zaria.

PARAMETERS	AGE		P- VALUE
	WEANERS	ADULTS	
FAM	3.33 \pm 0.02 ^a	3.24 \pm 0.02 ^b	0.005
PCV (%)	26.87 \pm 0.55	26.43 \pm 0.19	0.451
EPG (g)	798.59 \pm 77.56 ^a	563.17 \pm 87.69 ^b	0.045
BW (kg)	12.76 \pm 0.24 ^a	25.54 \pm 0.26 ^b	0.000

Means with different superscripts on the same row are significantly different (P<0.05)

Means \pm SEM of FAMACHA© Eye score (FAM), Packed Cell Volume (PCV), Egg per gram (EPG) and Body Weight (BW) of Goats by Season examined at a Research Institute, Zaria are shown in Table 4.1.6

There was statistical significant difference ($p < 0.05$) in the mean FAMACHA of goats in the wet season 3.34 ± 0.02 when compared to the mean scores of 3.25 ± 0.02 during the dry season.

The mean PCV in goats by season was lower 25.13 ± 0.18 in the wet season and higher 27.75 ± 0.48 in dry season. The difference between the mean values was statistically significant ($P < 0.05$).

The mean EPG in the goats was higher 1269.63 ± 112.71 in the wet season and lower 252.70 ± 54.03 in the dry season and the differences was statistically significant ($P < 0.05$).

The mean BW in the goats by season was 21.05 ± 0.32 in wet season and 17.76 ± 0.36 in dry season, and the difference between the two values was statistically significant ($P \leq 0.05$).

Table 4.1.6: Means \pm SEM of FAMACHA® Eye score (FAM), Packed Cell Volume (PCV), Egg per gram (EPG) and Body Weight (BW) by Season of Goats examined at a Research Institute, Zaria

PARAMETERS	SEASON		P- VALUE
	WET SEASON	DRY SEASON	
FAM	3.34 \pm 0.02 ^a	3.25 \pm 0.02 ^b	0.004
PCV (%)	25.13 \pm 0.18 ^a	27.75 \pm 0.48 ^b	0.000
EPG (g)	1269.63 \pm 112.71 ^a	252.70 \pm 54.03 ^b	0.000
BW (Kg)	21.05 \pm 0.32 ^a	17.76 \pm 0.36 ^b	0.000

a, b: Means with different superscripts on the same row are significantly different ($P \leq 0.05$)

The mean percentage larval recovery of gastrointestinal nematode species recovered from culture of the pooled faecal samples of goats examined at NAPRI Shika, are shown in Figure 4.1. The overall mean recovery in the wet season was significantly higher from that of the dry season.

Five different species of parasitic helminths were recovered. The mean percentage of *Haemonchus* L₃ recovered from the faeces of the goats during the monthly sampling at a Research Institute ranged from 54.94% - 65.33%. Then highest recovery rate coincides with the period of rainy season when faecal egg counts were highest (fig 4.1). Other larvae recovered were those of *Trichostrongylus* 13.19%-16%, *Oesophagostomum* 10.67- 19.78%, *Strongyloides* 5.33-8.79% and *Bunostomum* 2.67-3.29% species.

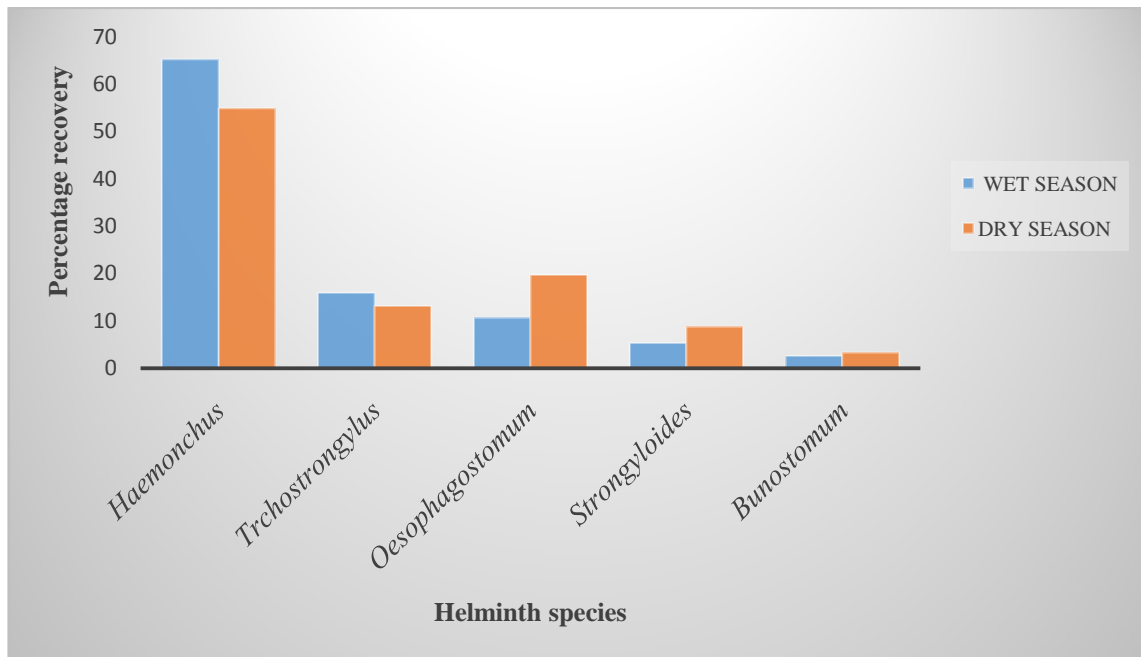


Figure 4.1. Percentage recovery of different helminth genera from pooled faecal cultures examined at a Research Institute Zaria. N=64

The comparative efficacy of the three most commonly available and frequently used anthelmintic for goats in the Nigerian market and imported ones are shown in table 4.2.

According to Coles *et al.* (1992), resistance is present if (i) the percentage reduction in egg count is less than 95% and (ii) the 95% confidence level is less than 90%. However, when only one of the two criteria is present, resistance is suspected.

There is a significant difference between the three anthelmintic used. For the imported albendazole, the percentage reduction in FEC recorded was 65.90%. The locally made albendazole 1, 2 and 3 had percentage reduction of 93.81%, 59.94% and -12.72% respectively. Imported ivermectin (drench and injectable) had a percentage reduction of 97.45% and 99.51% respectively. The imported levamisole had a percentage reduction of 98.93%, while the locally made levamisole had a percentage reduction of 99.52%.

Table 4.2. Mean Faecal Egg Count pre- and post-treatment (FEC-pre; FEC-post), and Mean Faecal Egg Count reduction percentages (FECR), in four goats flocks. Goats. N=700

Anthelmintic Type	Treatment Adopted				
	Dose	Mean before treatment	FEC	Mean after treatment	% FECRT
Imported ALB	5 mg/kg	1285.07		438.21	65.90
Locally sourced (ALB)1	0.5 mg/kg	2420		149.70	93.81
Locally sourced(ALB) 2	10 mg/kg	930.22		372.67	59.94
Locally sourced (ALB)3	10 mg/kg	617.25		695.75	-12.72
Imported IVM (drench)	3 mg/5kg	1582.32		40.4	97.45
Imported IVM (Injectable)	0.2 mg/5kg	1583.39		7.69	99.51
Imported LVM	12.5 mg/kg	2076		22.31	98.93
Locally sourced LVM	7.5 mg/kg	2495		12	99.52

ALB-Albendazole IVM- Ivermectiin LVM- levamisole

Based on farms visited, Damau and Farakwai had 100% reduction for all the treatment groups. Albendazole, ivermectin and levamisole showed zero epg after treatment.

For Kurmi, ivermectin drenched and injectable showed 100% and 99% reduction respectively against all worm species found, levamisole gave 90% reduction, Imported albendazole gave 94% reduction while the locally sourced one (1, 2 and 3) reduced faecal egg counts by 70%, 94% and 94%, respectively.

In NAPRI, ivermectin drenched and injectable gave 96% and 100% effectiveness respectively against all worm species found, imported and locally sourced levamisole gave 99% reduction each, imported albendazole had a negative reduction of -35% (mean FEC after treatment is greater than mean FEC before treatment), locally sourced albendazole (2) gave a reduction of 97%, while locally sourced albendazole (3) also gave a negative reduction of -291%.

Before treatment, the faecal culture revealed *Haemonchus* spp. as the predominant parasite with the percentage recovery of (73% and 65%), followed by *Trichostrongylus* spp. (10% and 18%), *Oesophagostomum* spp. (7% and 10%), *Strongyloides* spp. (5% and 6%) and *Bunostomum* spp. (3.57%) for the Research Institute and Kurmi respectively.

The faecal culture of each group after treatment again showed *Haemonchus* spp. as the predominant parasite with the highest occurrence rate (54 and 57%), followed by *Trichostrongylus* spp. (29 and 24%), *Oesophagostomum* spp. (8 and 12%), *Strongyloides* spp. (2 and 6%) and *Bunostomum* spp. (4%) for the Research Institute and Kurmi respectively.

Hence, anthelmintic resistance against locally made albendazole and levamisole was observed in Kurmi, whereas anthelmintic resistance was observed for both imported and locally made albendazole (3) for all worm species at the Research Institute.

Table 4.2.1: Mean faecal egg count pre- and post-treatment (FEC-pre; FEC-post), and Mean Faecal Egg Count Reduction percentages (FECR), in Damau Goat flocks.

Sampling Units	Treatment Adopted		Mean FEC before treatment	Mean FEC after treatment	%FECRT
	Anthelmintic Type	Dose mg/kg			
Damau Village	Imported ALB	5mg/kg	3947	0	100
	Locally sourced ALB (1)	0.5mg/kg	3315.79	0	100
	Local sourced ALB (2)	10mg/kg	352.85	0	100
	Local sourced ALB (3)	10mg/kg	6769	0	100
	Imported IVM (drench)	3mg/5kg	827.58	0	100
	Imported IVM (Injectable)	0.2mg/5kg	429.13	0	100
	Imported LVM	12.5mg/kg	0	0	100
	Local sourced LVM	7.5mg/kg	745.33	0	100

ALB- Albendazole IVM- Ivermectin LVM- Levamisole

Table 4.2.2. Mean faecal egg count pre- and post-treatment (FEC-pre; FEC-post), and mean faecal egg count reduction percentages (FECR), in Farakwai goat flocks.

Sampling Units	Treatment Adopted		Mean FEC before treatment	Mean FEC after treatment	% FECRT
	Anthelmintic Type	Dose			
Farakwai Village					
	Imported ALB	5mg/kg	0	0	100
	Locally sourced ALB (1)	0.5mg/kg	0	0	100
	Locally sourced ALB (2)	10mg/kg	4560	0	100
	Local Made ALB (3)	10mg/kg	2800	0	100
	Imported IVM (drench)	3mg/5kg	0	0	100
	Imported IVM (Injectable)	0.2mg/5kg	3825.11	0	100
	Imported LVM	12.5mg/kg	4805	0	100
	Local sourced LVM	7.5mg/kg	1633.33	0	100
ALB- Albendazole IVM- Ivermectin LVM- Levamisole					

Table 4.2.3. Mean faecal egg count pre- and post-treatment (FEC-pre; FEC-post), and mean faecal egg count reduction percentages (FECR), in Kurmi goat flocks

Sampling Units	Treatment adopted		Mean FEC before treatment	Mean FEC after treatment	% FECR T
	Anthelmintic Type	Dose mg/kg			
Kurmi Village	Imported ALB	5 mg/kg	865.45	49.09	94.33
	Locally sourced ALB (1)	0.5 mg/kg	1204.29	352.86	70.70
	Locally sourced ALB (2)	10 mg/kg	351.67	18.33	94.79
	Locally sourced ALB (3)	10 mg/kg	2253	117.78	94.77
	Imported IVM(drench)	3 mg/5kg	212.72	0	100
	Imported IVM (Injectable)	0.2 mg/5kg	9220	53.33	99.42
	Imported LVM	12.5 mg/kg	0	0	100
	Locally sourced LVM	7.5 mg/kg	805	76.67	90.48

ALB- Albendazole IVM- Ivermectin LVM- Levamisole

Table 4.2.4. Mean faecal egg count pre- and post-treatment (FEC-pre; FEC-post), and mean faecal egg count reduction percentages (FECR), in Shika goat flocks

Sampling Units	Treatment adopted		Mean FEC before treatment	Mean FEC after treatment	%FECR T
	Anthelmintic Type	Dose mg/kg			
Shika Village	Imported ALB	5 mg/kg	507.62	688.19	-35.57
	Locally sourced ALB (1)	0.5 mg/kg	0	0	
	Locally sourced ALB (2)	10 mg/kg	28720	694.17	97.58
	Locally sourced ALB (3)	10 mg/kg	296.59	1161.77	-291.71
	Imported IVM(drench)	3 mg/5kg	2208.64	67.8	96.93
	Imported IVM(Injectable)	0.2 mg/5kg	1583.39	0	100
	Imported LVM	12.5 mg/kg	2076.15	15.68	99.25
	Locally sourced LVM	7.5 mg/kg	2495	3.87	99.85

ALB- Albendazole IVM- Ivermectin LVM- Levamisole

The Mean Percentage recovery of gastrointestinal nematode species From culture of Pooled Faecal Samples of Goats Examined at a Research Institute , Damau, Kurmi and Farakwai in Kaduna State during anthelmintic trial are shown in Fig 4.2., 4.3., 4.4.and 4.5.

During the anthelmintic trials, the Research Institute had the highest mean percentage of L₃ recovered. Adult goats had mean percentage of 73.21%, 10.71%, 7.14%, 5.36% and 3.57% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* respectively while the weaners had mean percentage of 67.26%, 11.14%, 13.09%, 2.38% and 5.36% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* respectively.

Damau had mean percentage of 66.13%, 17.74%, 8.06%, 4.84% and 3.23% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* respectively.

Kurmi had mean percentage of 65.15%, 18.18%, 10.6% and 6.06% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, and *Strongyloides* respectively.

While Farakwai had mean percentage of 59.48%, 20.92%, 10.46%, 5.88% and 3.27% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* respectively.

For larval recovery after treatment, the Research Institute had mean percentage of 54.41%, 29.41%, 8.82%, 2.94% and 4.41% for *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* respectively, while Kurmi had mean percentage of 57.41%, 24.49%, 12.24%, and 6.12% for *Haemonchus*,

Trichostrongylus, *Oesophagostomum* and *Strongyloides* respectively. Damau and Farakwai had zero recovery after the treatment.

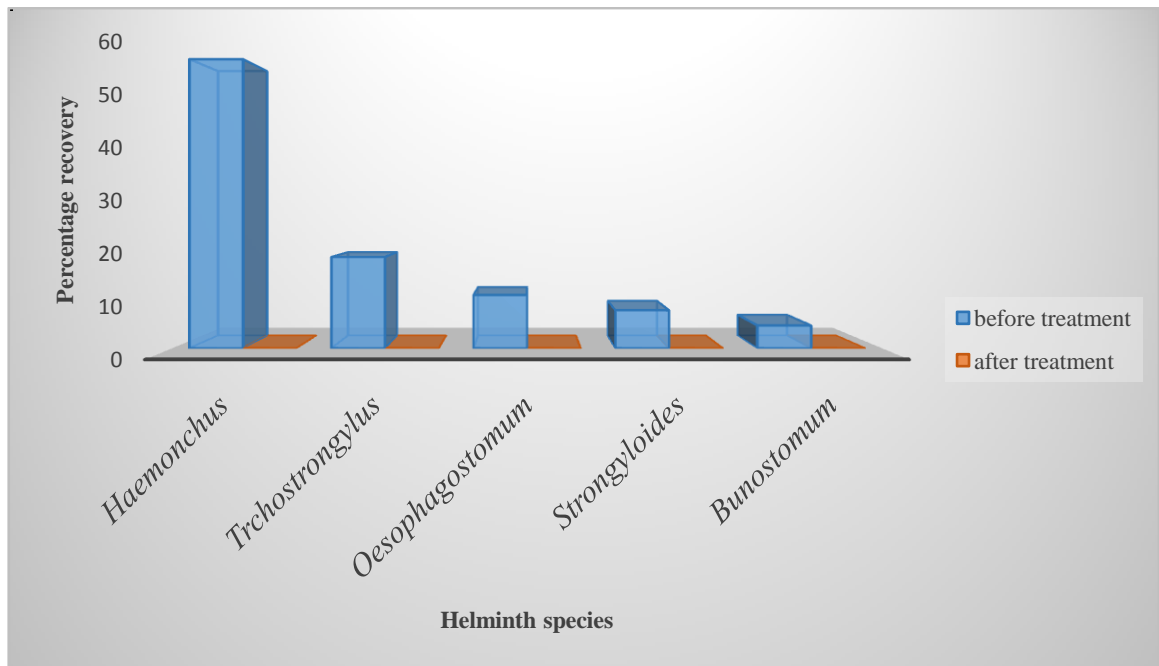


Figure 4.2. Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal cultures examined at Farakwai during anthelmintic trial.

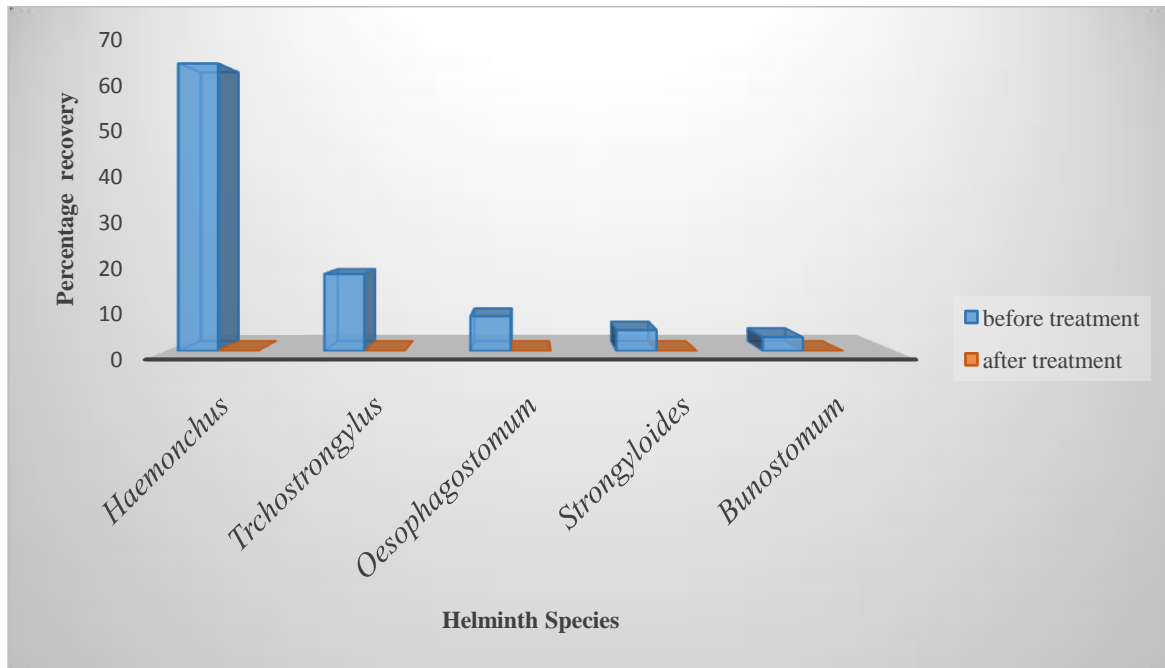


Figure 4.3. Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal cultures examined at Damau during anthelmintic trial.

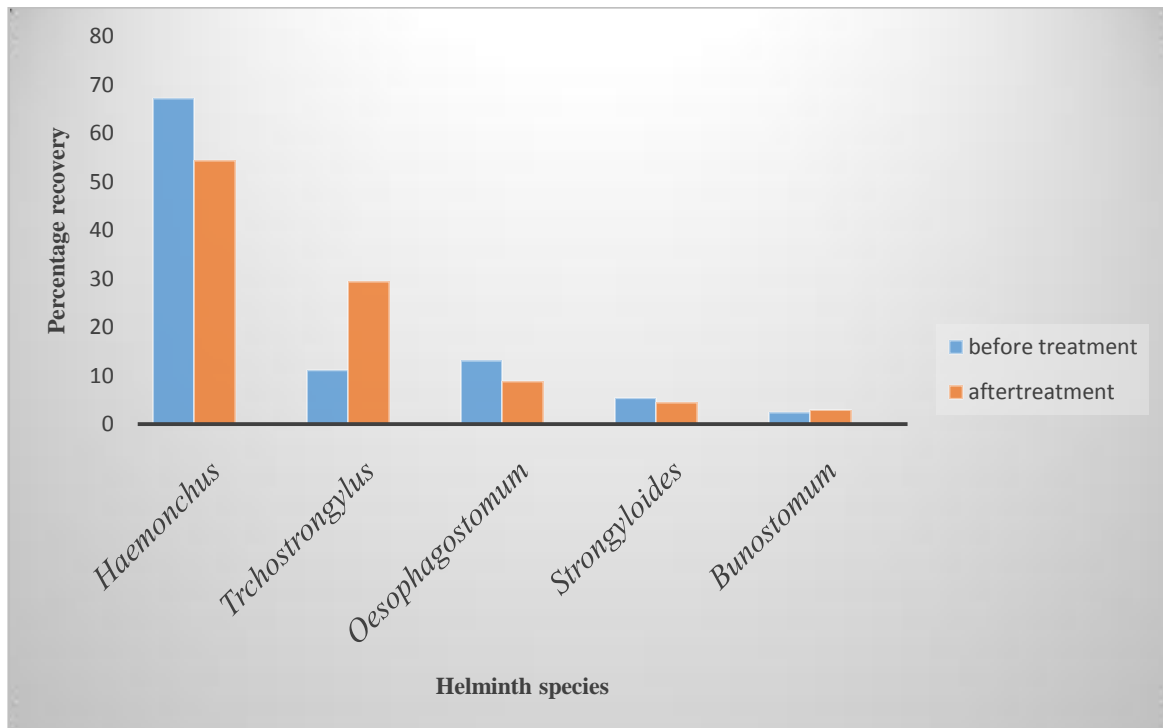


Figure 4.4. Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal cultures examined at a Research Institute during anthelmintic trial.

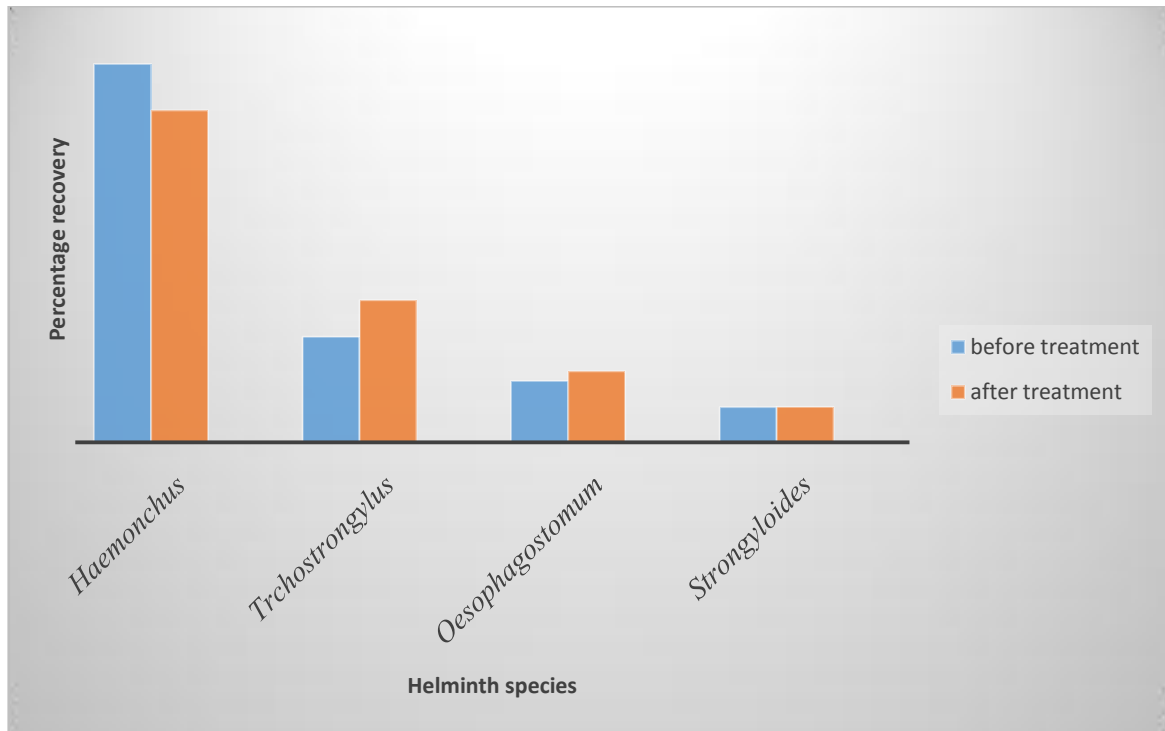


Figure 4.5. Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal cultures examined at Kurmi during anthelmintic trial.

CHAPTER FIVE

DISCUSSION

This study was aimed at using the FAMACHA method as a selective tool in delaying the development of anthelmintic resistance by *Haemonchus contortus* in Red Sokoto and Sahel Goats in four Local Governments Areas of Kaduna State.

In the present study, the PCV, EPG, and BW were evaluated using the colour of the ocular membrane of the goats. The findings of the mean PCV of the goats based on their FAMACHA© categories indicates the ability of FAMACHA© eye score to predict anaemic goats and consequently those that may require treatment in the case of haemonchosis. With these, fewer animals are treated and the development of anthelmintic resistance in worm population will be slowed down. In the long term, elimination of non-resilient animals will allow for the breeding of better adopted goats. The strong significant negative correlation between the eye scores and the anemia indices (PCV) allow us to presume that the FAMACHA chart was used correctly and further underscores its values as an indicator of anemia in goats. It can be further deduced from the results that with respect to normal values for PCV, goats with FAMACHA© score of 5 were severely anaemic and those with scores of 4 are marginally anaemic. Goats with FAMACHA© scores of 2 are those within the upper limit of the normal range for goats (normal range- PCV=22-40; Tambuwal *et al.*, 2002). The results of the present study suggest that eye score values of 3 could be used as FAMACHA© cut-off for indicating anaemic animals. This findings agreed with the reports of Idika *et al.* (2012), who carried out a preliminary study on the evaluation of anaemia in Nigerian goats using FAMACHA© eye colour chart and conclude that eye score value of 3 could be used as FAMACHA© cut-off for indicating anaemic animals.

Scheuerle *et al.* (2010) reported a sensitivity of 93% when FAMACHA treatment cut-off of ≥ 3 was used in evaluating the accuracy of FAMACHA in diagnosing anaemia and haemonchosis in Switzerland, using the anaemia criteria of PCV ≤ 30 , and epg ≥ 600 epg as cut-off values for treatment. In the work of Kaplan *et al.*, (2004), a similar FAMACHA treatment cut-off of ≤ 3 had sensitivity of 93.9 and 100 %, respectively, for PCV cut-off of < 19 and < 15 in goats. Idika *et al.* (2012) carried out a preliminary study on the evaluation of anaemia in Nigerian goats using the FAMACHA eye colour chart reported a PCV cut-off $\leq 28\%$ and FAMACHA cut-off ≤ 3 are likely the most appropriate treatment cut-off criteria to be used in detecting goats that have succumbed to haemonchosis and thus require treatment in Nigeria and concluded that the FAMACHA method can be used by farmers in Nigeria to identify anaemic goats

This study also demonstrated a strong correlation between FAMACHA and PCV, FAMACHA and BW, EPG and PCV, EPG and BW, as well as FAMACHA and EPG, PCV and BW.

FAMACHA and EPG, PCV and BW were positively correlated. This means that as FAMACHA score increases, the EPG increases, and as the FAMACHA score decreases, the EPG also decreases. So also as the PCV increases, the BW increases and as the PCV decreases, the BW decreases. The positive correlation between FAMACHA score and EPG agrees with that of Sangster *et al.* (1979) and this might be attributed to the intensity of infection with *H. contortus*.

The correlation between FAMACHA and PCV, FAMACHA and BW; EPG and PCV, EPG and BW were all negatively correlated. This implies that as the FAMACHA scores increases, the PCV and BW decreases and as the EPG increases, the PCV and BW decreases and vice versa. The result on negative correlation between FAMACHA and

PCV, EPG and PCV agreed with the earlier result of Kaplan *et al.* (2004); Burke *et al.* (2007) in the united states, Riley and Van Wyk. (2009) in South Africa, where they recorded a negative correlation between FAMACHA and PCV, EPG and PCV. The negative correlation is likely due to the blood sucking effects of the adult *H. contortus* worms since it as been reported that each worm could sucks 0.05 ml daily (Martin and Ross 1934 and Urquhart *et al.*, 2000).The negative correlation between FAMACHA and PCV was significant and demonstrated that the FAMACHA©-system was used correctly and provided a proof of the general usefulness of the method for the detection of anaemia under Nigerian conditions.

This study shows that the mean FAMACHA scores and BW were not significantly affected by breed, while the Mean EPG and PCV were significantly affected by breed. This result is in contrary with the result of Makun *et al.*, 2008; Kahn *et al.*, 2003; Pralomkarn *et al.*, 1997, where they recorded higher EPG in Sahelian than in the Red Sokoto. This result may be suggestive of the relative resilience of the Red Sokoto, even though the EPG and FAMACHA scores was high, it did not negatively affect their PCV and BW. This high EPG in Red Sokoto in this study could be attributed to genetic factor and management practice.

The low PCV observed in the sahelian goats agrees with the work of Makun *et al.* (2008) in North - western Nigeria which also showed a low PCV for the sahelian and this might be attributed to the fact that the sahelian are less capable of containing infection with *H. contortus*. The research of Baker *et al.* (1998), found differences in the two indigenous breed of goats, where the small East African goats were more resistant to gastrointestinal nematode infection than the Galla because the later showed significantly higher FEC and lower PCV, with a marked and persistent peri-parturient

rise in FEC than the small East African goat. Similar research by Mugambi *et al.* (1997) showed that sheep also exhibit resistance between breed, they showed that the black-headed Dorper Somali sheep was more susceptible to *H. contortus* on the basis of its higher egg count and lower PCV than the Red Masai sheep.

Based on body weight, the Red Sokoto goat had higher weight than the Sahelian but not significantly different. This agrees with the work of Makun *et al.* (2006) who recorded higher weight gain of 66 and 40 g day⁻¹ for the Red Sokoto and Sahelian kids respectively within the same experimental environment.

The study revealed that sex of the animal did not show significant difference in the occurrence of infection. These findings were similar to the reports of Keyyu *et al.* (2003); Regassa *et al.* (2006) and Ghanem *et al.* (2009). However, female animals had higher EPG. This agrees with the reports of Dagnachew *et al.* (2011) who reported a higher infection in females. This may be attributed to the immunosuppressive effect of reproductive hormones of the female animals especially during pregnancy and periparturient period (Soulsby, 1986 and Urquhart *et al.*, 1996). In contrast, Gualy *et al.* (2006) and Raza *et al.* (2007) documented higher prevalence of helminth infection in rams than in ewes.

This study indicates that, young small ruminants were more at risk of helminths infection than the adults. The higher prevalence in the younger animals could be suggestive of a higher susceptibility of the younger animals. These findings were in agreement with reports of Melkamu, (1991); Fritsche *et al.* (1993); Keyyu *et al.* (2003); Ng'ang'a *et al.* (2004); Githigia *et al.* (2005); Regassa *et al.* (2006); Dagnachew *et al.* (2011) and Welemehret *et al.* (2012) where they recorded high prevalence of infection in younger animals. Age was considered an important risk factor in GIT helminthosis

(Raza *et al.*, 2007). Several authors have documented that adult animals develop acquired immunity (Urquhart *et al.*, 1996; Taswar *et al.*, 2010) against helminth infections as they mature due to repeated exposure (Dagnachew *et al.*, 2011) and this will help expel the parasite before it becomes established in the GIT (Dunn, 1978; Shah-Fischer and Say, 1989).

The observed results of high PCV in the dry season could be as a result of variety of factors (adverse macro- and micro-environmental conditions, immune response of the host, parasite genetic constitution, among others), a phenomenon called hypobiosis occurs during the dry season, in which L4 diminishes its metabolism, halts its development and remains inside the gastric gland. The low PCV observed during the wet season could possibly be as a result of resumption from hypobiosis and the blood-sucking effects of the adult *H. contortus*, each of which can suck 0.05 ml daily (Martin and Ross 1934 and Urquhart *et al.*, 2000).

Similar results have been reported in other countries where *H. contortus* is the major problem of sheep and goats production (Miller *et al.*, 1998; Vatta *et al.*, 2001; Kaplan *et al.*, 2004). Infection with *Haemonchus* spp may cause severe anaemia and hypoproteinemia, leading to depression, loss of condition, reduced productivity and eventually death (Shaibani *et al.*, 2009). The disease tends to be more severe in young kids and lambs and particularly in lactating females where their immune status is compromised (Menkir *et al.*, 2007).

The observed results, of highest EPGs during the rainy seasons, were in accordance with studies in other countries in Africa with distinct rainy and dry seasons (Ghana: Agyei, 1991; Kenya: Maingi *et al.*, 1993; Nginyi *et al.*, 2001; Zimbabwe: Pandey *et al.*, 1994). This can be attributed to the high biotic potential of *H.*

contortus, resulting in this parasite rapidly taking up dominance at times when environmental conditions on pasture are favourable for the development and survival of the free-living stages. In addition, overstocking, which is a major problem in many African communal pastures (Hansen & Perry, 1994), may have contributed to the observed increased availability of infective larvae of gastrointestinal nematodes on pasture during the wet season.

Furthermore, Ng`ang`a *et al.* (2004) also suggested that during the dry season, herbage cover at grazing pasture is reduced due to overgrazing by animals. This may expose the larvae to desiccation, resulting in high mortality or deeper migration into the soil.

The improved performance of the experimental animals during the wet seasons is likely to be compensatory weight gains due to the availability of fresh grass during the growing season.

The depression of weight gain during the dry season may be due to loss of appetite (Bisset *et al.*, 2001), due to inflammatory changes in the abomasum's wall cells during the larval and adult stages (Beriajaya and Copeman, 2006).

The result of Experiment 2 showed the level of efficacy and resistance of most of the available anthelmintic used for the treatment of small ruminants. There are several reasons for the appearance of AR. One possibility is that a genetic mutation spontaneously develops within a parasite population that enables it to survive treatment. Together with too frequent and/or inappropriate dosing, which may lead to a selection of unsusceptible strains and to a continuous buildup of a resistant population. A further possibility is that animals carrying resistant GINs are introduced into a flock. A lot of goats are still treated according to the dose of sheep, although it is well known that the pharmacokinetics and the efficacy of anthelmintics vary between sheep and goats

(Sangster *et al.*, 1991, Chartier *et al.*, 2000). The metabolism of drugs is much quicker in goats, thus reducing drug availability (Alvinerie *et al.*, 1999), a fact which may contribute to a reduced efficacy or even a failure of treatment. Because of this, it is recommended to adapt the treatment dose to the special metabolism of the goats by increasing it to two fold of the sheep dose (Hennessy *et al.*, 1993; Alvinerie *et al.*, 1999).

In Experiment 2, Anthelmintic resistance was suspected in the four goat flocks visited. The results clearly indicates the existence of AR of Gastrointestinal helminths against benzimidazole group in goats of the studied flocks. While IVM and LVM were found to be effective.

The high potency (100% reduction) recorded for all the anthelmintic used in the two local farms may be probably due to infrequent dosing by these resource-poor farmers. This agrees with the work of Yadav *et al.* (1993); Gill, (1996); Ram *et al.* (2007) where they recorded the highest potency 99% of Fenbendazole at double the recommended dose, ivermectin and levamisole respectively against gastro intestinal nematode parasites in goats.

The FECRT performed in the first commercial farm revealed a high level of resistance of GIT helminths against Imported Albendazole, Locally made ALB 1, 2 and 3 and locally made LVM. The AR observed may be due to overuse of these group of drugs during routine deworming. These results are in line with previous findings of AR in sheep and goats farms in Western Europe (Hertzberg and Bauer, 2000; Bauer, 2001 and Artho *et al.*, 2007) where they recorded a substantial degree of AR of *H. contortus* against albendazole and thus indicate a high prevalence of AR. The observed resistance against LVM may be due to inappropriate dosing which may lead to a selection of

unsusceptible strain and a continuous build-up of resistance among parasites Population. These result agrees with that of Uppal *et al.*, (1992) However IVM was found to be most effective against GIN in the study farm. This agrees with the work of Gill (1996); Ram *et al.* (2007) who recorded the highest potency of ivermectin against gastro intestinal nematode parasites in goats.

For the second Commercial Farm, the FECRT revealed a substantial degree of resistance against the Imported ALB and locally made ALB 3. The reduced efficacy may be due to inappropriate dosing method or as a result of limited range of pasture being grazed on permanently with long-term use of these anthelmintic during routine deworming without monitoring the efficacy. These result are in line with the findings of Artho *et al.* (2007); (Bauer, 2001) and Van Wyk (2001). The routine deworming with albendazole group which were extensively used in the studied farm for several years has probably made these anthelmintic ineffective in controlling the clinical infections, indicating the emergence of resistance to these anthelmintic. Presently the FECR has increased to -291.7% (FEC after treatment is greater than FEC before treatment). This indicates a rapid emergence of AR, since the anthelmintic are being used too frequently. The rotation between drugs of the different anthelmintic classes on an annual basis can help to slow down the development of these resistance (Coles and Roush, 1992; Sangster, 2001).

The locally made ALB 2, the IVM and LVM groups were found to be highly effective against gastro intestinal nematodes in the studied farm. This might be attributed to the less frequent use of these group of drugs for deworming in this Farm. This agrees with the work of Gill (1996); Ram *et al.* (2007) who recorded the highest potency of

ivermectin and levamisole respectively against gastro intestinal nematode parasites in goats.

The findings on copro-culture revealed that *H. contortus* is the predominant gastrointestinal nematode parasite infecting the goat in all the farms studied with highest larval recovery of 73.21%. A similar prevalence has been reported by other researchers in this and other geographical zones of the country (Fabiya 1970; Okon and Enyenihi 1975; Fakae 1990; Nwosu *et al.*, 1996; Mbaya *et al.*, 2009). The main pathogenic effect of *H. contortus* is anaemia due to active blood sucking and bleeding from the haemorrhagic bite wounds caused by the worms (Soulsby 1982). Another blood sucking gastrointestinal nematodes capable of causing anaemia which were also observed during this study was *Bunostomum spp.* (3.5%).

The higher prevalence rate in the wet season recorded in this study may lend support to the general concept that moisture, humidity and high temperature are bionomic factors that support the development and survival of the infective stage of most of these parasites. This result agrees with the findings of Hansen and Perry (1994); Urquhart *et al.* (1996) and Almalaik *et al.* (2008). High prevalence rate in the wet season is also a true phenomenon in sub-Saharan Africa (Teklye, 1991).

The result of the larval culture during the anthelmintic trial showed larval recovery after treatment for only the ALB group at the two Commercial farm. The helminth genera recovered are *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum spp.* This result indicates gastrointestinal nematode resistance against the ALB group. *Haemonchus* seems to have the highest percentage recovery and this can be attributed to the fact that *Haemonchus* can acquire resistance to environmental factors faster than other gastrointestinal nematodes, like *Trichostrongylus*, because of its high

biotic potential (Torres-Acosta *et al.*, 2003). This probably account for it high prevalence than other genera encountered in this study.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

This study aimed to determine the FAMACHA method as a selective tool to delay the development of anthelmintic resistance of *H. contortus* in goats. Faecal Egg Count, Blood PCV, Body Weight and the FAMACHA scores of the goats were evaluated during the study. The Correlation between the FAMACHA, PCV, FEC and BW were determined. Risk factors such as breed, sex, age, season and anthelmintic efficacy of mostly used anthelmintic were also determined.

This study indicated the highest percentage recovery of gastrointestinal nematode at copro-culture as 73.13% in goats, with the highest percentage recovery during the wet season. This confirmed that the weather conditions of the wet seasons were generally favourable for the development, survival and transmission of the free-living stages of these parasites. The helminth spp recovered were *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides* and *Bunostomum* spp. Of these helminths, *Haemonchus* was recorded in higher number than other spp encountered during the study. Faecal Egg Count Reduction Test revealed high level of efficacy to the ivermectin and levamisole in most farms except for Kurmi where resistance to levamisole was suspected and gastrointestinal nematode were highly resistant to albendazole. Therefore, it is important to establish new treatment schemes, like targeted treatment, to prevent the further spreading of resistance.

FAMACHA© is a system, which can be used for the accomplishment of Targeted Selective Treatment. The method works for the clinical evaluation of anaemia in ruminants and is competent of detecting infections with blood-sucking *Haemonchus*

spp. The system determines the degree of anaemia by scoring the colour of the eye mucosa from category 1 (red = non-anaemic) to 5 (white = highly-anaemic), based on the FAMACHA©-colour-chart. Goats from 4 farms were scored for anaemia. Simultaneously, PCV and EPG were individually ascertained. EPG, PCV and FAMACHA©-scores were statistically compared to evaluate the efficacy of FAMACHA© in detecting *H. contortus* infections.

6.2 CONCLUSION

The overall high prevalence of gastrointestinal helminth and polyparasitism in the study area indicates gastrointestinal helminthosis to be an important health problem. *Haemonchus* was recorded high in prevalence and in copro-culture which indicates *Haemonchosis* is a serious problem in the study areas as reflected by high FAMACHA scores, high EPG, low PCV and body weight in goats.

The Red Sokoto goats were able to tolerate *H. contortus* infection because they exhibited high PCV, and body weight even though they have higher faecal egg count than the Sahelian goat. There was no statistical significant differences between male and female, however the females had higher EPG than the male and these could be as a result of immunosuppressive effect of reproductive hormones especially during pregnancy. The weaners had high EPG and low body weight than the adults and this may be as a result of undeveloped immunity against helminth infection in the young ruminants. The result showed high FAMACHA scores, high EPG and low PCV during the wet season and this could be due to the high biotic potential of *Haemonchus contortus* resulting in this parasite rapidly taking up dominance at a time when environmental condition on pasture is favourable for the development and survival of the free living stages.

The study shows the presence of anthelmintic resistance to the albendazole group and high level of efficacy to ivermectin and suspected resistance to levamisole in goats in the studied farm.

Moreover, the present study found that, provided a high prevalence of *H. contortus*, the FAMACHA©-method is capable of detecting the animals in need of anthelmintic treatment under Nigerian conditions. Further studies in Nigeria are urgently needed to evaluate whether the practical application of the FAMACHA©-method by the farmers can reduce the number of anthelmintic treatments without decreasing the productivity of the flock.

6.3 RECOMMENDATION

Based on the findings of the present study as well as field observations, relevant approaches for helminth control could include:

- Appropriate anthelmintic usage to restore anthelmintic efficacy and prevent resistance to occur in gastrointestinal nematode. Recommendations include the use of the most suitable drugs, correct dosage, treating selectively rather than the entire flocks and avoiding high frequency/repeated treatments.
- Provision of animal health extension services, which includes regular monitoring of faecal egg output of selected animals, assessment of anaemia using the FAMACHA chart, and treatment of animals based on the outcome of these analyses.
- FAMACHA eye score could be included in the management strategies of controlling helminthoses in small holder farmers.
- Farmers that were involved in the drug trials should be advised of the most appropriate anthelmintic of choice based on the most effective drug.

- Studies on the molecular analysis of the respective resistant gene loci will be of great importance in order to characterize the resistant GIN strains.

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APPENDICES

Appendix I: Percentage recovery of different helminth genera recovered from pooled faecal culture of Adults goats examined at a Research Institute Zaria.

L3 RECOVERED	PERCENTAGE RECOVERED	
	BEFORE TREATMENT	AFTER TREATMENT
<i>Haemonchusspp</i>	73.21	0.00
<i>Trichostrongylusspp</i>	10.71	0.00
<i>Oesophagostomunspp</i>	7.14	0.00
<i>Strongyloidesspp</i>	5.36	0.00
<i>Bunostomumspp</i>	3.57	0.00

Appendix II: Percentage recovery of different helminth genera from pooled faecal culture of weaned goats examined at a Research Institute Zaria.

L3 RECOVERED	PERCENTAGE RECOVERED	
	BEFORE TREATMENT	AFTER TREATMENT
<i>Haemonchusspp</i>	67.26	54.41
<i>Trichostrongylusspp</i>	11.14	29.41
<i>Oesophagostomunspp</i>	13.09	8.82
<i>Strongyloidesspp</i>	2.38	2.94
<i>Bunostomumspp</i>	5.36	4.41

Appendix III: Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal culture examined at Damau.

L3 RECOVERED	PERCENTAGE RECOVERED	
	BEFORE TREATMENT	AFTER TREATMENT
<i>Haemonchusspp</i>	66.13	0.00
<i>Trichostrongylusspp</i>	17.74	0.00
<i>Oesophagostomunspp</i>	8.06	0.00
<i>Strongyloidesspp</i>	4.8	0.00
<i>Bunostomumspp</i>	3.23	0.00

Appendix IV: Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal culture examined at Kurmi Kaduna.

L3 RECOVERED	PERCENTAGE RECOVERED	
	BEFORE TREATMENT	AFTER TREATMENT
<i>Haemonchusspp</i>	65.15	57.41
<i>Trichostrongylusspp</i>	18.18	24.49
<i>Oesophagostomunspp</i>	10.6	12.24
<i>Strongyloidesspp</i>	6.06	6.12

Appendix V: Percentage recovery (pre and post treatment) of different helminth genera from pooled faecal culture examined at Farakwai.

L3 RECOVERED	PERCENTAGE RECOVERED	
	BEFORE TREATMENT	AFTER TREATMENT
<i>Haemonchusspp</i>	59.48	0.00
<i>Trichostrongylusspp</i>	20.92	0.00
<i>Oesophagostomunspp</i>	10.46	0.00
<i>Strongyloidesspp</i>	5.88	0.00
<i>Bunostomumspp</i>	3.27	0.00