COMPARATIVE GROWTH RATE, MILK PRODUCTION, AND RESISTANCE OF THE RED SOKOTO AND SAHELIAN BREEDS OF GOATS TO EXPERIMENTAL *HAEMONCHUS CONTORTUS* INFECTION.

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DECLARATION

This work has been undertaken and written by me under the guidance of Professor O.J Ajanusi, Professor O.W Ehoche and Professor C.A.M Lakpini. No part of this work has been presented in any form for award of a higher degree. The research findings of other scientists have been acknowledged by means of references.

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Makun, Hussaina Date

CERTIFICATION

This thesis entitled **"Comparative growth rate, milk production and resistance of the Red Sokoto and Sahelian breeds of goats to experimental *Haemonchus contortus* infection"** by Makun, Hussaina meets the regulations governing the award of the degree of Doctor of philosophy (PhD) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This Dissertation is dedicated to
the LORD ALMIGHTY who it had pleased
to take those dearest to my heart to be with HIM and for
memories of my dad, twin brother, Abu and Habiba.

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ABSTRACT

The aim of the study was to evaluate the production potential and relative resistance to *Haemonchus contortus* of Red Sokoto and Sahelian breeds goats fed basal diets of Digitaria *simutsii* supplemented with concentrate. In experiment 1, five multi-parous does of each breed were placed on intensive management following kidding and d*oes* were hand-milked twice weekly. The average birth weight of the Sahelian (2.2±0.17) was significantly (P<0.05) higher than the Red Sokoto kids (1.0±_0.17). At weaning, the average kid weight of the Sahelian (5.6± 0.12) was significantly higher (P<0.05) than the Red Sokoto (3.7± 0.12). Breed had significant (P<0.01) effect on the milk solid and milk fat content, with the Red Sokoto producing higher milk solid and fat. Experiment 2 was conducted to compare the growth rate of the two breeds. The respective mean birth and weaning weights (kg) for Red Sokoto kids were 1.00±0.17 and 7.5±0.64 compared to the respective corresponding values of 2.2±0.17 and 7.8±0.64 for the Sahelian. The average daily gain was significantly higher (P<0.05) for the Red Sokoto (66.9±1.59g/day) than the Sahelian kids (46.6±1.59g/day). Experiment 3 was conducted to determine the relative resistance of Red Sokoto and Sahelian kids to experimental *Haemonchus contortus* infection. Fifteen goats of each breed were either given $0L_3$/kg (treatment 1), 75 L_3/kg (treatment 2) or 100 L_3/kg (treatment 3), three times weekly for 3 weeks. The mean faecal egg output expressed in eggs per gram (epg) was significantly higher (P<0.05) for the Sahelian (1477±153.4) than the Red Sokoto (607±147.5). The mean total protein was statistically different between breeds, the Red Sokoto being higher (P<0.05) than the Sahelian (64.6± 1.81 Vs 57.6± 1.86). In Experiment 4, the study was as in

Experiment 2 using lactating goats. The Red Sokoto were included in the no infection (control), low infection (75L3/kg live weight) and high infection level (100/kg live weight), levels while the Sahelian does were only included in control and low infection groups. The faecal egg count showed significant variation for treatment ($P<0.05$) but not for breed. The eggs per gram for the control, low and high infection levels were 1.3 ±131.91, 647.4±120.23 and 274.1±190.35 respectively. The control, low and high infection levels had milk yields of 132.8±8.58, 252.8±7.35 and 237.8±11.93ml/day. The Packed Cell Volume (PCV) was significantly ($P<0.05$) affected by infection levels but not by breed. The PCV of the control, low and high infection levels were 26.7±0.69, 25.0±0.59 and 23.5±0.95% respectively. Similarly, the albumin concentration varied significantly ($P<0.05$) for breed and infection levels. The Sahelian goats had higher albumin concentrations (35.7±0.67g/lt) than the Red Sokoto goats (33.7±0.56). Overall, the albumin concentrations for the control, low and high infection groups were 35.7±0.70, 33.3±0.66 and 34.9±0.91g/lt respectively. The total protein concentration was significantly affected by breed and not by infection levels. The Sahelian had higher levels (65.7±1.33g/lt)than the Red Sokoto (63.1±0.80g/lt). It was concluded that the Red Sokoto were able to resist the experimental *Haemonchus* infection based on the lower faecal egg output, slightly higher PCV and average daily gain than the Sahelian.

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LIST OF ABBREVIATIONS

CD	=	Cluster designation
g	=	Grams
EPG	=	Eggs per gram
FAO	=	Food and Agricultural Organization
FEC	=	Faecal egg count
IgA	=	Immunoglobulin A
IgE	=	Immunoglobulin E
IgM	=	Immunoglobulin M
dl	=	Decilitre
PCV	=	Packed cell volume

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Helminthosis in small ruminants and goats in particular, is of considerable importance because it affects production through losses due to mortality and reduced weight gain (Tembely *et al.* 1996). In Nigeria, between 1970 and early 1980s, the losses due to helminthosis were estimated at N14 million ($107,672) annually (Okon, 1998). Similarly, Bitta *et. al*. (2006) reported an annual loss of $81.1 million to helminthosis. Schillhorn van Veen (1973) estimated losses of about 11% of the economic value of goats to helminthosis. The most important nematodes responsible for economic losses in Nigeria include species of *Haemonchus, Gaigeria, Oesophagostomum, Trichostrongylus* and *Trichuris* (Fabiyi, 1970). Amongst these nematodes, *Haemonchus contortus* has the highest prevalence (Fabiyi, 1970; Ikeme, 1997). The effect of helminths on production depends on the age (Stear, Strain and Bishop, 1999) and physiological status (Okeyo *et al.*, 1996) of goats, season of the year, management practices (Tembely *et al*., 1996) and infective dose (Magona and Musisi, 2002)

Adult animals are known to be able to resist to some extent the severe effects of helminthosis on production performance. However, in young, pregnant and lactating animals, the consequences of helminthosis are usually severe, which could be attributable to impairment of immune responses ((Tembely *et al.*, 1996). Abbott *et al*. (1985) demonstrated a significant effect of dietary protein on establishment of haemonchosis in Finn Dorset lambs but not in Scottish blackface lambs. Similarly, Wallace *et al.* (1995) demonstrated the improvement of the carcass

composition of lambs supplemented over those not supplemented when infected with *Haemonchus contortus*. It is therefore, suggestive that differences observed in feeding behaviours of different breeds of goats may be responsible for the differences in the host immune response to susceptibility encountered in experimental and natural nematode challenges (Hoste *et al.*, 2001). In East Africa, Shavulimo (1989) observed that the Small East African goat was more tolerant to *Haemonchus contortus* than the Gall goat. In Nigeria there is evidence of breed resistance by zebu cattle to *Haemonchus contortus* infection but this study was not conclusive and it was not extended to other breeds and species of livestock (Adejimi and Harrison, 1996). The confirmation of evidence of breed resistance has been documented in different studies of genetic variation to the effect of helminths. The genetic variation is usually observed when the animals are able to reduce the length of the worms and reduce the fecundity of the female worm (Stear *et al.*, 1999; Fakae *et al.*, 1999; Costa *et al*., 2000).

The development of resistance to gastro-intestinal nematodes also influences the level of milk yield. In their studies Charteir *et al*. (2000), and Charteir and Hoste (1997) showed that the high producing dairy goats were less resistant to both natural and experimental nematode infection than the low-producing dairy goats, but that resistance or resilience may be improved by a protein supplementation. In Africa and Nigeria in particular, heritability estimates for resistance and its correlation with growth, reproduction and dairy traits are lacking for our indigenous goats.

The management or husbandry practices employed by farmers would either encourage or limit spread of helminths from one group of animals to another. With goats kept by landless farmers, rotational grazing becomes impossible and cross- infection occurs regardless of the age of animals. The best strategy to control these parasites will be through participatory education of

these landless women farmers to practice strategic deworming (Borgsteede *et al.*, 1998; Tembely, 1998., Bakunzi and Serumaga-Zake, 2000). This strategic treatment is usually out of reach for this category of farmers who just keep these animals for their adaptive qualities to harsh environment. Most importantly, the recent trend of anthelmintic resistance in small ruminants as has been reported in most continents of the world (Fernandez *et al.*, 1997; van Wyk *et al.*, 1997; Charteir *et al.*, 1998; Zajac and Gipson, 2000). Resistance renders anthelmintic therapy ineffective and limits its use in reducing the effects of infection on production. *Haemonchus contortus* has been reported to be resistant to different anthelmintics (Waruiru, 1997). In addition its devastating effect on livestock and its arrested developmental strategies propels its destructive consequences on small ruminant productivity.

As a result of anthelmintic resistance seen in some helminths, other means of controlling endoparasitism are being sought. There are reports on different methods of reducing the effects of helminths on livestock production through biological control, vaccination and selective breeding (Meeusen *et al.*, 2007; Ralthore *et al.*, 2007; Smith *et al.*, 2007). A fungus, *Duddingtonia flagrans*, has been identified by Larsen *et al.* (1997) and Waller, Knox and Faedo, (2001), as the most promising biological agent for controlling parasitism, but its commercial application will limit its success. Siefter and Rickard (2000) and Kabagambe *et al.* (2000) used gut proteins of *H. contortus* to immunize livestock for protection against haemonchosis. The benefits of this method will be more enhanced in livestock that are known to tolerate the effect of parasitism through selection. It is therefore important to evaluate the level of tolerance to these parasites in all breeds of goats that act as hosts to determine which breed is more tolerant to haemonchosis. To determine the effect of haemonchosis on production performance of these goats, their production performance should be documented without infection.

In Nigeria, the works of Chiejina *et al.* (2002), and Fakae *et al.* (1999) were carried out among the West African Dwarf goat. There has been little or no evaluation of the predominantly northern breeds of goats; the Red Sokoto and Sahelian breeds, within their ecological environment to determine their level of tolerance to *Haemonchus contortus*. Likewise, the patho-physiology of *Haemonchus contortus* on growth rate and milk production is yet to be determined in all the species of livestock, including goats in Nigeria. It is therefore possible that the susceptibility to gastrointestinal nematodes could be different between the breeds of goats found in Nigeria.

1.2 JUSTIFICATION

The global population of goats in the last 2 decades has increased (Dhanda *et al.* 2003), but the reasons for the increase differs between developing and developed countries. In the developed world, this increase may be as a result of consumer preference for goat milk and the change in the citizenry, whereas in developing countries the change is due to higher demand for goat meat in the urban areas which provides readily available cash for the rural goat farmers. Notwithstanding the reason for the change, goats have been recognised in the livestock system as the species of animals that can respond to this demand because they are efficient milkers and highly prolific, and are able to utilize degraded land; hence they are able to thrive under conditions that other species cannot cope with. In addition, to these qualities goats have made goats companions of the resource-poor farmers particularly women and children, who because of their limited resources, subject these goats to poor management, inadequate housing and poor health practices. With the above poor management disease is one of the most important

constraints to goat production and helminthosis ranks highest in reducing production gains with *Haemonchus contortus* as the most prevalent worm of economic importance (Okon, 1998).

Haemonchus contortus, an abomasum-dwelling nematode parasite is responsible for most of the production losses due to the blood-feeding habit of both larval and adult stages as well as its hypo-biotic mechanism of survival (Gatongi *et al.*, 1998). In addition to its damaging effect, *Haemonchus contortus* in recent years has been reported to exhibit resistance to a wide range of drugs in different species of animals including goats (Fernandez. *e. al.*, 1997; Sangster 1999; Bartley *et al.*, 2003). Several attempts, such as genetic selection and immunization with antigens are strategically being evaluated to control the devastating consequences of these nematodes. These include selecting animals that are genetically resistant and/or immunizing animals using antigens obtained from different parts of the nematode (Jasmer and McGuire, 1991; Liddell and Knox, 1998). A study in Australia and New Zealand showed some benefits in genetically selecting animals that are resistant to endemic parasites (Adams, 1988) and this probably coupled with nutritional supplementation, may go a long way in ameliorating the effects of these helminths. Selection criteria like faecal egg count, host antibody response and parasite presence, are among the tools used as indices to genetically select resistant animals. Similarly, immunization using antigens obtained from the membrane or gut have been used to protect animals with varying results. All these non-therapeutic methods of helminth control are yet to get commercial value even in the developed countries. In developing countries, Nigeria in particular, these strategies are yet to be evaluated in our indigenous livestock. These non-therapeutic methods of helminth control may be one of the options that can improve the goat production in Nigeria, since these options may require minimal resources in the long run and will minimize the

amount of drug residue in food animals. There is the need to determine the tolerance and resistance characteristics of our all our breeds of livestock.

1.3 OBJECTIVE

To determine the growth rate, milk production, and resistance of the Red Sokoto and Sahelian of goats to *Haemonchus contortus*.

Specific objectives include:

- Determine the growth rates of the Sahelian and Red Sokoto breeds of goats from birth to one year of age.
- Determine the milk production potential of the Sahelian and Red Sokoto breeds of goats.
- Compare the effect of experimental *H. contortus* infection on growth rate of Sahelian and Red Sokoto breeds of goats.
- Determine the response of lactating Sahelian and Red Sokoto breeds of goats to experimental *H. contortus* infection.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Agriculture has been the main source of a sustainable livelihood of the world for centuries. In some areas especially in the developed countries, agriculture still remains a source of livelihood for a limited number of the population owing to advancement in agricultural practices. The numbers of farms in developed countries are very few with large investment, large animal population and larger returns due to rapid human population growth and technological advancement amongst others (Devendra, 1997).

In the developing countries, the situation is in contrast, where, agriculture still employs more than 50% of the population, characterized by small number and size of animals and farms (Devendra, 2001).

The farming population even though have maintained and sustained their production, is still employing technologies that have been in use for centuries. The rate of adoption of new technologies is slow, because such technologies usually emanate from the scientist with little or no knowledge of the tangible and non-tangible benefits of the farming systems of these rural populations (FAO, 1996). Therefore, agriculture in the developing countries has remained at smallholder levels with less than 5% owing large farms. These smallholder farmers are involved in crop, livestock or mixed farming. They are predominately found in the humid and subhumid zone of developing country; keeping about 75% of the livestock population. The production system can be grouped into crop-livestock and pastoralists production systems.

The intensive livestock production is just emerging with less than 2% of the farming population practicing this system of management. These intensive farms are characterized by large landed property located in urban or peri- urban areas, large number of animals kept indoors or stall-fed using preserved pastures. Under this system the production performance of such animals are usually at par with those of their counterparts in the developed countries. Whereas with the extensive system of management, the smallholder farmer, graze animals exclusively on range with little or no supplementation. Usually such crop-livestock farmer owns between 2-15 animals (Devendra, 2000) and about 2 hectares of land used for cultivation of crops (Bebe *et al.*, 2003). Under these production systems, animals are fed crop residues with little or no supplement, and manure from the animal is returned to fertilize the soil. Production indices here are usually low (such as, low growth rate and milk production) and disease prevalence is high.

Similarly the pastoralists have low production indices due to their management practices. Animals are usually communally grazed in large numbers by nomads. Feed is obtained from the rangeland with little or no supplementation. At least 2 species of ruminants are kept to complement each other during grazing. These make up to 20% of the livestock in the crop-livestock production. Animals that make up these production systems include the cattle, sheep and goats (Sieff, 1999).

2.2 SMALL RUMINANT PRODUCTION

The need for more milk has increased the population of dairy goats by 52% in the world, 56%, in developing countries and 17% in developed countries in the last 20years (Heinlein, 2004) while the sheep population has decreased by 3% in the world by 6% and 14% respectively in the developed and developing countries during the same period (Dhandra, 2003; Vander-Zipp, 1999). It is estimated that there are about 407 and 123 breeds of sheep and goat respectively in

the world (Shrestha, 2005) with approximate populations of 1064 and 700 million respectively (Haenlein, 2001). Most knowledge required for goats is usually an extrapolation from sheep or down- sizing of cattle to obtain goat data. This may be due to fact that small ruminants have always been kept by the resource - poor farmers who may be the landless and voiceless women (Jaitner *et al.,* 2001) having minimal interaction with the extension personnel. It has been reported that about 10 industrial nations leading among which is Greece, depend on goats for 30 - 76% of their total milk supply. Meanwhile, the other industrialized countries like the United States which hitherto did not consume goat products is now changing because of demographic changes across the globe where there is now cultural diversity due to immigration of its citizens from Asia, Africa and the Middle East, thereby encouraging introduction of small ruminant which hitherto had been in very negligible numbers (Haienlein, 2001). The contribution of small ruminants based on a farm management survey by Panin and Mahbile (1997) showed that small ruminant enterprise is profitable and viable, providing a 34% return on investment and contributing 15% of household income to the rural populaces. Most of the contributions of small ruminants are in the tangible area of providing meat, milk, fibre and manure but other intangible contributions, which are usually not evaluated, are their use for exchange, cultural and religious purposes.

In their studies, Guevara *et al.* (1995) established that sheep and goat production will remain profitable even when chevron/mutton and kid prices decrease respectively, as the contribution from sheep wool and goat is about 70%and 58% of the gross income. Apart from the contribution of goats in the house- hold in terms of cash returns, one of the most significant contributions of goats in the household is the provision of milk (Cisse *et al.,* 2002) to infants and

old, thereby combating and reducing under or malnutrition in resource-poor farmers. Other unquantifiable contributions include their use for cultural and religious activities as well as soil fertility through manure production. Therefore, improving the goat production will directly increase cash flow and improve nutrition of infants in such neglected areas.

2.2.1 Goat Production

The approximate world goat population was 715 million in 2000, with 95% in developing countries (Devendra, 2000). Asia had 60% of the total goat population with India having the largest population of goats (Dhanda *et al.*, 2003). Goats account for 30% of Africa's ruminant livestock and the population of goats in sub-Saharan Africa (SSA) is estimated at 147 million (Lebbie, 2004). Sixty-four percent of the goats are found in the arid and semi-arid zones, sub-humid, humid and high lands accounting for 17. 9 and 10% respectively (Bogoro, Niba, and Butswat, 1999). Goats produce about 3.7 million metric tones of meat (Chevron) annually, representing 16% of total meat production. In Africa however, goats produce 17% and 12% of its meat and milk respectively. There is no accurate figure of its contribution to human food security because the use of goat products at the rural household is not recorded and at national levels goat products are sold and or exchanged through informal markets (Devendra, 2001). In essence, goats contribute to the rural households in more varied ways other than cash flow. Their consumption and sale enhance economic stability of household during crop failures and financial fluctuation. Goats are usually the sacrificial animals not only when financial needs arises but also as payment of bride price and ritual rites.

Thus they are considered as current account by the resource-poor farmers who are usually women. Jaitner *et. al.,* (2001) reaffirmed other worker's report that 67% and 52% of goat and

sheep owners respectively were women. Goats lend themselves to these landless resource-poor farmers because of their special attribute that does not require heavy capital investment and their high adaptability to a variety of environments. Goats are able to convert poor quality feeds to animal food products consequently playing a significant role in improving the income of the rural farmer (Sieff, 1999). The average number of goats kept by these women range from 3 – 10 goats per household (Makun *et al.*, 2005).

Lebbie (2004) described goats as been able to graze and browse poor quality forages and shrubs. These qualities are usually due to their skillful grazing behaviour and efficient digestive system enabling them to obtain maximum food intake and utilization (Silanikove, 2000; Fedele *et al.*, 2002). Sometimes they walk long distances to obtain the required feed. These attributes are then transformed into animals with high fecundity (Kosgey *et al.*, 2005), short generation interval (Bosman *et al.*, 1993), efficient milk producing ability (Greenwood, 1993), and generation of high turn over on an investment even in the worst arid environments.

In sub-Saharan Africa goats are raised in a variety of ways, but rarely in intensive management. They are either raised in a communal farming system or allowed to roam in search of feed (Mahanjana and Cronje, 2000, Bebe *et al.*, 2003). The communal system is found in the sub-humid and Sahelian regions and individuals, own between 3 – 10 goats which are combined and herded as a community, this may total up to a thousand goats. Goats in such herds consisted usually mainly of 76.7% does and 23.3% bucks, indicating that females were preferentially retained in the system for the purpose of reproduction. Within this system there is usually

insufficient feed due to the large number of goats. Consequently, this leads to high incidence of abortions and death particularly in young animals (Mellado *et al.,* 2004).

Free range goat production is the predominant system. Unlike the communal farming, this system allows the goats to roam throughout the non-cropping season. In the night and during cropping season, goats are tethered in the home stead and feed is cut and carried to them. Goats in this system invariably are kept along with cropping of food and cash crops in a crop-livestock production system. This system is characterized by inadequate feed, particularly during the growing season (Devendra, 1997). Within this system also, households keep between 2 – 5 animals which are given supplements in form of kitchen waste. This system is predominant in the humid zone where there is a lot of arable crop farming (Olaloku, 1985). In the nomadic or pastoral system, goats are herded along with cattle and sheep over long distances. During the grazing, goats are able to complement the other ruminants by grazing or browsing those plants that will otherwise not have been consumed by either sheep or cattle. Hence, depending on the environment, goats are able to adapt and utilize the scarce resources for maximum productive gain.

2.2.2 Goat Breeds

There are 102 recognised breeds of goats throughout the world with live weights ranging from 9 to 13kg for small Tropical breeds to over 100kg for large improved dairy breeds (Dhanda *et al.*, 2003). The differences in size are in the form of the long-legged breeds to the stocky improved and short-legged West African Dwarf. Goats are kept usually for meat and mature weight of bucks range from 14 – 120kg while that of females is from 8 – 90kg, and height at withers is from 45 – 100cm for bucks and 40 – 85cm for does.

In Africa, it has been documented that there are about 80 recognised breeds of goats in the population. The predominant indigenous breeds of goats found in Sub-Saharan Africa (SSA) are documented below. In South Africa, the Small East African breed is predominant while the Kigezi breeds are found more commonly in Eastern part of Africa. The West African dwarf, Red Sokoto and the Sahelian breeds are the most common in Western Africa and the Omani breed in North Africa. Despite the large genetic resources of these goats in Africa there has been no deliberate effort to conserve (Bege *et al.,* 2003) their specific genetic attributes. Instead, breeds like the Toggenburg, Alpine, Angora and Nubian have been introduced for the purpose of upgrading the indigenous population (Okello and Obwolo, 1984; Ayalew *et al.*, 2003).

In West Africa and Nigeria in particular, three prominent breeds of goats, inhabit this region. These include, the West African Dwarf, Red Sokoto (Maradi) and the Sahelian breeds.

2.2.2.1 The West African Dwarf breed

The West African Dwarf goats inhabit the humid and forest zone of West Africa. It is small-sized; short legged with black or white color and is believed to be trypano-tolerant (Odo, 2003). Its matured weight is between 15 – 25kg and it is mainly kept for meat. Their overall productivity indices vary depending on management either on-station or on-farm. There reproductive indices is also affected by the management practices

2.2.2.2 The Red Sokoto breed

The Red Sokoto (maradi) is the most important breed that is widely distributed in northern Nigeria (Makun *et al.,* 2005) and is estimated to be half of the total goat population in the country. It inhabits the sub humid and semi-arid regions of the country. It is medium- sized, approximately 65cm at the withers. Adults weigh between 20 – 25kg on farm, averaging about

30kg on station (Malau-Aduli *et al.,* 2003). One of its characteristics is that, it has a smooth reddish coat which is preferred for leather processing. The Red Sokoto is highly prolific with age at first kidding recorded at about 201days, with dams weighing about 11kg at first kidding. Even though goats are known to deliver a lot of twins, the scientifically documented kidding rate is 1.61 kids and a kidding interval of 260days.When twins are kidded, the combined birth weight is 3.5kg while the birth weight for single kid is averagely 1.9kg

2.2.2.3 The Sahelian

The Sahelian breed of goat is a long – legged, large breed. It is sparsely distributed along the semi-arid and arid regions of Nigeria, but most abundant in the republic of Niger, a boundary country to Nigeria (Shaib *et al.,* 1996). The breed has a short, smooth coat which is white in colour or sometimes mixed with brown or black. It has long pendulous ears, usually longer than the head. (Cisse *et al.,* 2002). It measures about 80 cm at the wither and weighs between 35 – 40kg at maturity (Alaku and Moruppa, 1983). The average birth weight for singles, twins and triplets are 2.7, 2.3, and 1.6kg, respectively, and average milk yield of 1kg per doe/day (Cisse *et al.* 2002). This high milk yield of the dam is to support the growth of the large-boned kids.

2.3. GROWTH PERFOMANCE

The growth rate of a suckling offspring depends on its own physical and social environment, and its dam's ability. The growth of the kids prior to weaning is a function of the dam's ability (Pfeffer and Rodehintscord, 1998) in providing adequate nutrition in milk to support the growth of the kids. After weaning, growth of kids is usually influenced by varying factors. Weaned kids will grow by increasing the tissue content of their body which becomes demonstrated by gradual increase in the live-weight of kids. Post weaning growth rate is affected by hereditary

factors and kid's ability to adapt to environmental conditions. The factors that influence the growth of goat kids include; birth type, breed, sex, feed availability, feed intake, supplementation and castration.

2.3.1 Breed

The breed of the kids plays an important role in their growth potential. Larger breeds of goats grow faster than small breeds of the same age (Pfeffer and Rodehintscord, 1998). Mahgoub and Lu (1998) showed that the large-sized Batina breed goat of Oman reached slaughter weight earlier than the small-sized Dhofari breeds. Although the Dhofari had higher growth rate relative to final body weight, the large Batina had higher proportions in the bony structure and muscles of the carcass. Similarly, Ruvuna *et al.* (1992) observed a higher live and empty body weight of kids from Galla dams than those from East African dams during slaughter, even though the animals had been kept under similar experimental conditions. These differences in attainment of live weight changes of different breeds may be influenced by ability of the breeds to efficiently utilize available feed resources. When three dominant breeds of goats in the United State were grazed on high and low protein quality, the most prominent difference was in their feeding behaviour. Even though the competition was similar between the breeds, the Angora was slightly more aggressive during feeding (Hart *et al.* 1993). In contrast Turner, Wildeus and Collins, (2005) did not observe any breed difference in weight gain when they evaluated high forage diet in goats.

2.3.2 Sex

The sex of the animals also determines the rate of its growth. Male goats grow at a faster rate than female goats of the same age. (Makun *et al.,* 2006) The male goat has less adipose tissue, and thicker bones. Consequently, it is able to convert feed to live weight more efficiently and carry more muscle fibres than the females. Hafez and Dyer (1969) further confirmed this by demonstrating that castration or removal of androgen secreted by the testis also reduced the thickness of the bones to that which is present in female. The phenomenon has been demonstrated by previous studies. When animals were fed and growth rate compared, the bucks grew faster (147g/d) than the does (92g/d) (Mahgoub and Lu 1998). Moreover, male animals are known to be more aggressive in the feeding behaviors and this becomes of advantage when feed is less abundant.

2.3.3 Feed Availability

One of the most peculiar natures of goats is their ability to thrive and produce meat and milk in conditions that are considered harsh (Silanikove, 2000). The availability of forages influences the diet that grazing goats will select (Fedele *et al.,* 2002, Goodwin *et al.,* 2003). Selective ability of goats is influenced by the breed of goats (Hart, Sahlu, and Fernandez, 1993), previous dietary experience (Morgard – Fehr, 1991) and forage availability (Iji *et al.,* 1995). Under normal conditions goats will prefer and select grasses over other food resources but when these grasses mature, goats are able to feed on browse plants to meet the feed requirement (Aganga and Monyatsiwa, 1999., Goromela *et al.,* 1999). Goats are able to meet their feed requirement in the mist of little because they have low body mass and low metabolic requirement. So when there is scarcity, goats are able to dramatically reduce their intake (Morand –Fedhr, 1991) to be able to

survive prolong period of drought (Abijaoude *et al.*, 2000). However, when there are abundant feed, goats like the other ruminants will graze the luscious grass by increasing their intake from 28g DM/kg 0.75W during the scarce period to 65g DM/kg 0.75W during periods of abundance.

2.3.4 Feed intake

Intake of feed by goats is dependent on its quality. High quality is usually more palatable and easily digested. Therefore, goats will normally have a high intake of good quality feeds. Feeds of good quality are usually grasses that are in their early growth, at which stage they are high in energy and protein. When they mature they become fibrous plants containing cellulose, hemi cellulose and lignin. The higher the intake of high quality feeds, the higher the digestibility and consequently availability of nutrient for utilization and growth. Higher intake of poor quality fibrous materials will lead to inefficient digestion and limited nutrient availability (Osafo *et al.*, 1994., Alcaide *et al.*, 1997., Makun *et al.*, 2001) but significantly improved intake is attained by supplementing stover with high proteinous feed. Hence when available feeds of fibrous nature, are provided it should be with other ingredients that will improve the digestion of these feeds. Usually they are provided with supplements that will improve their intake, digestion and utilization (Ogwang and Karua, 1994).

2.3.5 Feed supplementation

Supplementation of fibrous feeds has been found to be beneficial when feeding ruminants. In the tropics, where protein is the limiting ingredient, feed supplementation with nitrogenous feed has improved the growth performance of goats. Supplementation should be adequately planned to avoid substitution which occurs when the animal consume the concentrate diet in replacement to the basal diet offered. Supplementations have included the use of oil seed cakes (Titi *et al.* 2000;

Mui *et al.*, 2001), leguminous forages (Smith *et al.,* 1990; Schlecht *et al.,* 1999), agro- industrial by- products (Negesse, *et. al.,* 2001, Solaiman, *et. al.,* 2002) and browses (Goromela *et al.,* 1997; Patra *et al,.* 2003). Feed supplements are used either to provide rumen degradable nitrogen as in the case of leguminous plants and browses, or supply rumen undegradable nitrogen which by-passes the rumen to be utilized in the abomasums. Baba *et al.,* (1998) studied the effect of supplementation on the growth performance of lambs and kids raised under oil palm tree plantation; and concluded that kids and lambs that were supplemented had higher growth rate than the control kids. The supplemented kids recorded average daily gain (ADG) of 25.6g/day as against 2.0g/day in control kids. Similarly, Malau-Aduli *et al.* (2003) recorded ADG of 39.3g/day in supplemented Red Sokoto kids, with control kids losing weight when conventional concentrate ration was compared with crop- residue based supplements. In sheep, the liveweight gained increased significantly when graded levels of browses were fed.

The supplemented sheep gained weight in the range of 6.5 to 65.2g/per day while the control animals lost about -24.4g per day (Kaitho *et al.,* 1998). In developing tropical countries, where feed availability is poor, supplementation of livestock grazing natural range is very crucial to maintain or improve productivity. Supplementation should be adequately planned to avoid substitution which occurs when the animal consume more of the concentrate to replace the basal diet offered. In their studies Okello *et al.* (1996) demonstrated the principles involved in substitution when they supplemented goats with maize bran, cotton seed cake and fresh lurcerna leaves without observing any difference in the total dry matter intake.

2.3.6 Castration

Castration is the removal of the male reproductive organs usually prior to weaning to improve the growth rate and carcass quality of the meat in some animals like the buck. This is practiced

in countries like France, Spain, where goats are slaughtered at tender age; therefore, castrating them may be beneficial in increasing the slaughter weight of the kids (Ruvuna *et al.,* 1992). It was observed that castrated goats showed higher growth rate, conversion ratio and dry matter intake than intact males when both were fed barley based concentrate and Lucerne pellets (Muhikanbele *et al.,* 1994). Castration can increase external fat score of the carcass but decrease the internal fat (Mourad, Gbanamou and Balde, 2001).

2.3.7 Carcass evaluation

In France, Italy and Latin American, young milk-fed kids are usually slaughtered for meat (Anous and Mourad, 1993) while in India and Africa, meat of the matured animal is preferred. Thus, the liveweight at slaughter is higher in the developing countries than in the developed countries (Marichal *et al.,* 2003).

In areas where goats are eaten young, kids are removed from the dam at about 15 days of age, weighing between 5-6kg liveweight and slaughtered for meat. The carcass of such kids is usually very light weighing about 3kg. Development of subcutaneous fat is slow in goats, which is why goats have leaner carcasses compared to sheep; however, goat meat (chevron) is darker red than sheep meat (mutton). Age has an influence on the palatability of goat meat; meat from older goats is regarded to be juicier than younger ones. Similarly, studies on the chemical composition and quality of the meat suggest that the goat meat is not inferior to the lamb. The dressing percentage based on full live weight is usually in the range of 40-53% (Alaku and Moruppa 1983). Offal percentage for full gastro-intestinal tract (GIT) and empty GIT is reported to range between 14-30% and 8-12% liveweight at slaughter.

2.4 MILK PRODUCTION

Milk is the fluid secreted from the mammary gland of a mammalian animal to support the growth of the offspring following parturition. Milk from animal is meant to be suckled by their offsprings but man has interferred in the process by initially collecting the excess to the extent that the quantity left may not be able to support the offsprings. Animals that are normally milked for human consumption include cattle, buffalo, camel, sheep and goats. Cow milk is the accepted milk that is used as food for human infancy (Ijokjel *et al.*, 2000) but in Asian countries like Indian, Bangladesh, the buffalo (Bindal and Wadhwa 1993) contributes a significant amount of milk in the food chain of Asians. Although goat milk has been consumed in most Mediterranean regions in the past (Cabiddu *et al.*, 1999) it is only beginning to attract attention in other parts of the world (Dhanda *et al.*, 2003) probably due to the globalization of trade across countries. In Africa and Nigeria, goats are usually kept primarily for meat production. Mea *et al.*, (1994) reported that goats were being milked periodically by farmers throughout the year to feed children. Therefore, milk obtained from goats, particularly in non-dairy goats, is of small quantity.

2.4.1 Milk Yeild

The lactation curve of the goat is similar to that of cows where the dam mobilizes all body fat to support the high milk yield needed for the growth of the offspring, (Olori *et al.*, 1999). Depending on the breed and management, the average daily milk produced by goats (Salama *et. al.*, 2003; Pamo *et al.*, 2005) varies from 138g to 2000g (Soryal *et al.*, 2005). Following parturition the *doe* produces milk that gradually increases until it peaks at between the 3rd and 4th week postpartum, and this plateau before declining toward the end of lactation (Cisse *et al.*, 2002). The quantity of milk produced per lactation is influenced by many factors amongst which

are breed of dam, type of birth and parity of the dam. Dams that are in their first lactation may produce just enough to feed its kid. However with increasing parity, milk yield is increased but Mourad *et al.* (1992) reported that goats produce more milk in the fifth lactation after which production declines. D*oes* between 2 and 3years of age, usually have a flatter lactation curve (Maltz *et al.,* 1991). D*oes* usually mobilize their body reserves to maintain milk production, as evidenced by weight loss observed up to 6 weeks post partum (Eknaes *et al.,* 2006). This loss may however continue up to the end of the lactation (Djibrillou *et al.,* 1998) depending on the availability of feed resources to balance for mobilized nutrients in the milk. In early lactation there is usually a low energy intake which leaves the *doe* at a negative energy balance resulting in energy mobilization from body fat reserves to maintain milk production. Goats lose about 1kg per week in the first few weeks of lactation after which the loss reduces to between 0-0.5kg per week by the eighth week of lactation (Sutton and Alderman, 2000). Moreover, lactating animals in the tropics don't produce milk to their maximum potential because the animals are not usually in a body condition score (BCS) to allow for mobilization of fat. Hence tropical animals may be emaciated at the end of lactation (Cabiddu *et al.,* 1999).The body condition score of an animal is a practical tool used to assess the nutritional condition of the animals. Placed on a scale of 1-3, BCS can be used to indicate satisfactory state of animal on feed or pasture. There is a negative correlation between body condition score and milk yield. Increasing milk yield will result in a poor body condition score.

2.4.2. Milk composition

The chemical composition of milk of the different animal species is presented in Table 1. The average milk fat of goat milk varies between 2 and 5.27% (Sahlu *et al.,* 1993; Bhushan, *et. al.,* 1998), while protein varies from 3.28 to 3.6% (Salamal *et al.,* 2003). The total solids and solid

not fat are reported to be between 11.2 and 16.5%; 8.3 and 12.2%, respectively (Zeng, *et. al.*, 1997, Greyling *et al.,* 2004). The main difference between goat, buffalo and cow milk is in the fat content of the milk. The goat milk fat exhibit crystallization behaviour, thereby making the milk to be granular in texture, with a consistency and characteristic flavour, which is peculiar to goat milk. The fat content of goat milk consists of high concentration of medium chain fatty acids (Gulati *et al.,* 1997) which are involved in the treatment of a variety of mal-absorption syndromes, hence the therapeutic qualities of goat milk. (Bindal and Wadhwa, 1993). Similarly, the property of the short and medium chain fatty acids is responsible for the soft and high quality of goat cheese that makes it a highly acceptable commodity in the developed countries (Soryal *et al.,* 2003). Furthermore, it is reported that in dairy goats, the fat, protein and total solids are usually high in early lactation, decreasing as lactation peaks and increasing in late lactation when milk volume is low. The quantity and quality of milk is usually influenced by a lot of factors amongst which are the breed, parity, feed availability and type of birth (Kominakis *et al.,* 2000).

Table 1: Chemical composition of milk of different species of animals

Animals	Fat	Protein	Lactose	Ash	Total solids
Cow	5.50	3.3	4.7	0.76	14.3
Sheep	5-8.0	5-6.5	3.9-4.4		16-20
Goat (Temperate)	3.5-8.0	2.8-3.0	3.9-4.4		11.5-13.5
Goat (tropical)	4.2	3.5	4.8	0.79	12.9
Buffalo	6.6	3.9	5.2	0.8	15.8

Source Rahim, 1987.

2.4.3 Factors affecting milk production

2.4.3.1 Breed of goats

In Nigeria, indeed in most African countries, goats are kept for meat and rarely for milk. However, sometimes these goats are milked periodically and fed to children, thereby improving the protein intake of these children consequently combating malnutrition status of infants in the community (Lebbie, 2004; Makun *et al,*. 2005). Therefore, these goats are expected to produce milk like their counterparts which are bred and selected for the purpose of milk production. In the Mediterranean countries and France, goats have been selected for high milk production (Weifel *et al.,* 2004). Many research studies have demonstrated that certain breeds of goats produce more milk, with varying composition than others: (Rabasco *et al.,* 1993).

The Beetal X Barbari goats of India produced more milk (1040ml/day) and milk energy than the Jamunapari of India (780ml/day) or the Black Bengal X Barbari crossbred of India (669ml/day). The Nubian breed of the United States produced more milk and milk fat than Alpine breed as reported by Soryal *et al.,* (2003). In Tropical Bangladesh, Moralers *et al.,* (2000) and Sung, Wu and Wang, (1999) reported that the Anglo-Nubian cross-bred produced significantly more milk (780ml) than the Barbari (610 ml) and Barbari X Black bengal (430ml) breeds, with no significant difference between the Barbari and barbari X Black Bengal breeds. In South Africa, Greyling *et al.,* (2000) showed that the Boran breed of goat produced more milk (1.9litre/day) than the indigenous goat (1.4litre/day) managed under intensive or extensively system

In Nigeria, Bemji *et al.* (2005) compared peak milk yield and persistency of milk production between West African Dwarf (WAD) and Red Sokoto breeds raised under intensive management. They however, did not demonstrate any significant differences in the milk yield

between the WAD and the Red Sokoto goats (452 versus 437ml/day). Similarly Djbrillo *et al.* (1998) observed that the Red Sokoto breed had an average daily milk yield of 441ml/day. Ehoche and Bunanvarandra (1983) reported a mean daily milk yield of 545ml/day for the Red Sokoto goats. The Sahelian breed had a mean daily milk yield of 980ml/day when Cisse *et al.* (2002) supplemented with concentrate. Peak yield was observed to occur 4 weeks post-partum in the first parity, and at about 3 week's postpartum at the 2nd lactation.

2.4.3.2 Feed intake

Livestock production in most tropical countries depends on the availability of grazing land, since most production is predominantly on the natural pasture (Manyuchi *et al.,* 1997). The quantity and quality of the feed depends on climatic characteristics of the region and season (Ehoche, 2002). During the rainy season, grasses on the rangeland, grow rapidly with high nutritive value during the early rainy season, after which the plants mature rapidly with resulting reduction in nutritive value (Odo, *et. al.*, 2001). To minimize the adverse effect of poor feed availability, herbivores feeding on range land have two main foraging strategies. Either they maximally consume the high quality of forage by choosing plants or parts of plants that are of high crude protein content or they consume large amounts of the poor quantity within a short time resulting in higher rate of feed intake (Kababya *et al., 1993*,). Therefore, whether the goats are on range (Romero *et. al.,* 1994), pasture (Sibanda *et al.,* 1999) or on-station (Abijaoude *et al.,* 2000) improving the level of intake ensures better feed utilization. The grazing habits of goats allow them to be efficient users of available vegetation, under poor conditions such as the dry season where there is limited high quality and quantity pastures. In periods of inadequate pasture availability or during lactation when the nutrient requirement of the animal is increased, feed supplementation of animals becomes a necessity (Hill and Leaver, 1999). Supplementation using

commercial concentrates (Molle *et al.,* 1997; Chowdbury *et al.,* 2002) has shown beneficial response in terms of milk production in dairy goats. However, due to its high cost and unavailability of commercial concentrates, especially in developing countries, farmers search for other relatively cheap and available supplements such as forage proteins (Mui *et al.,* 2002), which may not provide all the nutrients required by high-producing lactating animals. In most dairy animals, one of the main limiting factors to milk production is energy intake (Sampelayo *et al.,* 1998; Schmidely *et al.,* 1998). Gulati *et al.* (1997) reported that feeding of fat supplements in the diet of ruminants increased the energy density of the feed, but most importantly, it enhances both milk and meat yield by improving nutrient utilization. This energy is usually available as glucose, which acts to control the movement of water into milk. Hence, milk production in goats therefore depends on the net energy of available forage. Greyling *et al*., (2004) investigated the milk potential of South African indigenous goats under intensive and extensive nutritional management and reported that does under intensive high energy diet had a higher milk yield (3.1L) than those kept under extensive management (0.8 L) even though the milk composition was not affected. To demonstrate the effect of protein on milk production, Andrighetto and Bailoni (1994) compared the effect of meat meal (MM) and hydrolysed feather meal (FBM) on the diet of dairy goats, and showed that milk yield was similar in animals on the two protein diets but there was significant difference in protein and casein content of the milk, high values being obtained in animals on FBM. However, when Salihu *et al.,* (1996) gradually increased the CP level (9-18%), milk production linearly increased (from 548 to 751ml/day). This response was more because wool growth in Angora *does* might have caused a higher demand for protein in these lactating does. Similarly Economides *et al.,* (1999) showed an increase of between 3-33% in milk yield of lactating does.

Even when crop residues were supplemented with urea in the diet of lactating does, the difference noticed was on the chemical composition rather than the milk yield (Djibrillou *et al.,* 1995., Zervas *et al*., 1998). Therefore, even when feed is produced in adequate amounts, other factors such as the parity, number of kids, age or weight of the dam also affect the amount of milk produced by the dam.

2.4.3.3 Parity of dam

Several authors have reported significant effects of parity on milk yield of does. Ciall, (1981) reported that milk yield increased gradually with age until between 3rd and 7th lactations, when therewas a decrease. In some studies, Mourad (1992), Rabasco *et al*. (1993) and Montaldo, Almanza and Juarez, (1997) showed that the 4th and 5th lactations gave, on average, maximum milk yield and this was usually when does were between 2 and 3 years, when they exhibited a flat but highly persistent lactation curve than either the younger or older does.

2.4.3.4 Live weight

The most important source of variation in milk yield is the body weight of the does. The body weight of does is however, related to the age of the animal. Therefore, Mourad (1993) reported that body weight of the dam is a source of variation in milk yield, if the age is held constant. Ihali *et al*., (1999) and Mavrogenis and Papachristoforou (2000) showed a positive correlation between total milk yield and body weight, whereby the higher the body weight the more the doe produced more milk. The body weight of the animal is also indicative of the feeding and management level of the farming system.

2.4.3.5 Litter size

Litter size also affects pre-weaning milk yield. Milk yield was affected by the number of kids. Does with multiple kids produced 11% more milk than goats with singles, while those without kids yielded 15% and 21% less compared to does with singles or multiples, respectively (Rabasco *et al.,* 1993). Also, Goonewardene *et al.* (1999) estimated the milk yield in non-suckled intensively managed dairy goats, and showed that *does* which had multiple kids produced more milk over the total lactation (807.6 Vs 664.6kg) compared to *does* that produced singles, but the milk composition was not affected by the multiple births.

The effect of litter size on milk yield is not just on the number of kids littered but also the number of kids being suckled. Salama *et al.* (2003) compared the effect of once versus twice daily milking, and reported that *does* which were milked twice daily produced more milk (1.95L/day) compared to those milked once daily (1.61L/day), the increase being more marked from week 2 to 12.

2.5 CONSTRAINTS OF GOAT PRODUCTION

2.5.1 Feed Shortage

Goat production in developing countries is in harsh environments with extremes of climatic conditions that adversely affect their production. Goats are found in the hot tropical regions as well as the temperate dry area. In these dry environments, there are extended periods of drought, characterized by feed scarcity and water. Even though the goats are able to support the rural family, there is no institutional policy that will encourage goat production in these areas. The government of Nigeria is yet to provide a policy that encourages goat production, as evident in the fact that most financial institutions in Nigeria don't recognize goat farming is an integral part of livestock production.

2.5.2 Diseases

Disease remains one of the most important factors militating against livestock production. The prevalence of diseases in small ruminants is usually associated with high mortality (Turkson, 2003) and decline in productive and reproductive performance. Odo (2003) and Voh *et al.,* (1993), reported that the most prevalent diseases of small ruminant were ecto-parasitic infestation (39.2%), helminthosis (31.8%) and pneumonia (20%). Similarly, Odo (2003) reported helminthosis to be one of the most prevalent diseases affecting goats in the South Eastern Nigeria. Helminthosis in small ruminants is of great importance in a wide range of agro climatic regions of Africa. It affects production through losses due to mortality, reduced weight gain (Tembely *et al.,* 1996), milk yield (Borgesteede *et al.,* 1998) and other production losses. However, effect of helminths on production depends on livestock species, age, breed, physiological status, parasite species and intensity of worm population in the definitive host. In Nigeria, it is estimated that about 11% of the economic value of goat is lost to helminthosis (Schillhorn van Veen, 1973).

2.6 HELMINTHS OF RUMINANTS

Parasitic helminths are worms that live on/in the body of another organism, competing with the host for nutrients (Blackburn *et al.,* 1991). These helminths are widely distributed in all geographical regions of the world; and are found in different predilection sites within the body of the host. The helminths that infect man, animals and birds belong to four classes namely nematoda (round-worms), trematoda (flukes), cestoda (tape-worm) and acanthocephalan (thorny headed worms) (Soulsby, 1982).

2.6.1 PREVALENCE OF PARASITIC NEMATODES

The most important parasitic nematodes of ruminants (small and large) responsible for production losses are mostly found in the gastro-intestinal tract and belong to the following genera; *Haemonchus, Trichostrongylus, Cooperia, Bunostomum, Gaigeria, and Oesohpagostomum* (Asraf and Nepote, 1990) in the case of the tropics. The presence of these parasites depends primarily on the species of ruminants and climatic factors that encourage their survivability (Ikeme, 1997). In various surveys of small ruminants (Anene *et al.,* 1994; Magona and Musisi, 2002) it was reported that the strongyles were more predominant, presenting economic burden for the farming family. *Haemonchus* however has the highest prevalent rates in ruminants (Fagbemi and Dipeolu, 1982, Githigia *et al.,* 2000; Agyei, 2003; Papadopoulo *et al.,* 2003,). The effect of helminths on livestock production depends on the age of the animal, physiological status, season of the year and management practices.

In surveys conducted by numerous authors, it was reported that most common class of helminths infecting ruminant s belong to the family trichostrongylidae family (Fabiyi, 1970; Fabiyi, 1973; Okon and Dipeolu, 1977; Nwosu *et al*. 1996; Ikeme, 1997).

In Nigeria helminths prevalence rates of 50-100% in small ruminants are known to occur all year around, with *Haemonchus contortus* having the highest prevalent rates (Fabiyi, 1970; Fabiyi, 1973; Umoh *et al.*, 1982; Tekdek and Ogunsusi, 1987). Fakae and Chiejina, (1993) monitored the prevalence rate of concurrent infection with Trypanosome and reported that the most prevalent nematodes were *Haemonchus* and *Trichostrongylus*. The presence and longevity of the larvae contaminating pasture and consequently the transmission of the larva depends on the

climatic factors. Strongyles are the most important parasite contributing to morbidity due to gastro-intestinal parasitism during the rainy season in Zaria (Fabiyi, 1973; Umoh *et al.,* 1982). Even though the prevalent rates of helminths in small ruminants are varied depending on the season of the year, prevalent rate could be up to 100%, infection occurring all year round (Fakae, 1990; Waller and Thomas, 1975; Tekdek and Ogunsusi, 1987). Surveys conducted by different authors (Fabiyi, 1970; Pandey 1990; Jacquiet *et al.,* 1992; Nwosu *et al.,* 1992; Mbaria *et al.,* 1995) showed that *Haemonchus contortus* recorded the highest prevalent rate of up to 90%, which was closely followed by the *Trichostrongylus* species (76%). In their study of the prevalence and seasonal changes of helminths of Nigerian goats, Nwosu *et al.*(1996) reported that *Haemonchus contortus* had 90%, *Trichostrongylus colubriforms,* 78.3%; *Strongyloides papillosus,* 80.8%; *Trichuris ovis,* 72.5%; and *Oesophagostum columbianum,* 67.50% in Ibadan area. Fabiyi, (1970) reported 89% *Haemonchus contortus*, 51% *Trichostrongylus colubriformis*, 47% *Oesophagustomum columbianum* and 53% *Trichuris ovis* in Zaria area. Similarly, Waruiru *et al.* (1994) demonstrated that young goats were more commonly infected, having higher worm counts than adult goats. Umoh *et al.* (1982) observed that most of the parasites were in animals older than 24 months. It is however possible that, these young animals which have survived their first rainy season, with arrested larva L_4, (Ogunsusi and Eysker, 1979) may show relatively higher helminths burdens in the following rainy season since they are yet to acquire any immunity against the different helminths. The strongyle infections were more observed in the rainy season between May and November in Northern Nigeria, (Fabiyi, 1973; Onwuliri *et al.,* 1993) because during the rainy season the environmental condition is conducive for the development of eggs and larvae of the helminths (Magona and Musisi, 2002).

Eysker and Ogunsusi (1980) reported that equal numbers of adults, developmental stages and arrested larvae were recovered during the months of April and May, but by June only adults and developmental larvae were in higher numbers, so that by mid August, high mortality were observed amongst lambs. At that point, the proportion of arrested larvae had diminished, and by October animals that had survived the infection may become adults showing symptoms of chronic haemonchosis in conjuncture with other helminthosis, notably trichostrongylosis. This phenomenon was further demonstrated by monthly monitoring of pasture, contaminated with 3 species of helminths, in Addis Ababa which has a cool tropical climate (Tembely, 1998). In the hot tropics, Agunloye *et al.*, (2002) reported the presence of infective larvae during June, July August and September in a 2 year study in Ibadan, Southwestern Nigeria. The study further demonstrated that infective larvae remained viable 2-6 weeks after eggs were deposited on pasture.

On the other hand in the Southern Nigeria, where the rainfall and temperature is adequate for more than 7 months, Odo (2003) and Okon and Dipeolu (1977), reported that livestock acquire infection all year round. Also in southern Nigeria, *Haemonchus contortus* survives the dry season as adults without arrested larvae (Fakae, 1990). In the Sahelian region of Senegal, Vercuysse (1985) examined abomasa of sheep within a period of 13 months and reported that adult helminths were predominant during the rainy season.

2.6.2 Effect of age

Under natural grazing management, kids are usually exposed early in life to different pathogenic organisms in the environment (Agyei, 2003). These pathogenic organisms include helminths, protozoa, bacteria and viruses amongst others. Therefore, the kid does not suffer from a single

infection. Successful establishment of the infection will depend on other factors like, nutrition, environment, management and immunity. The time kids were first exposed to contaminated pasture; either the dry or wet season will determine survival of the larvae and consequent infection. In an earlier study, Durie and Elek (1966) and Aumont *et al.* (1997) observed that the rate of mortality in calves was dependent on when these calves were first exposed to contaminated pastures. Calves that were first exposed to pasture during the months of higher rainfall suffered 93% mortality as compared to those calves exposed during the drier months that recorded a 63% mortality rate. One of the factors responsible for this difference is that during the wet season, the high humidity and moisture are conducive for larval development and survival (Jacquiet *et al,.* 1996). Kids are twice more at risk of developing helminth infection than adults due probably to low immunity to these parasites, since it is observed that it is only when the kid advances in age that it is able to resist the infection and develop immunity (Torres-Acosta *et al.,* 2006). Therefore, kids that are usually exposed to trickle infection during the dry season, may develop immunity before exposure to a more contaminated pasture in the next rainy season. Magona and Musisi (2002) in evaluating the most important epidemiological factors of gastrointestinal strongylosis showed that young goats had higher mean worm egg counts than adult goats, after which the worm egg output declined during the first year of life and stabilized to level where the infection remained steady and low. Green *et al.* (1999) reported that serum antibody concentrations to Trichostrongyles were found to be heritable in parasitized lambs from 3 months of age and above, an indication of maternal involvement in immunity to the worm.

In developing countries, where there is nutritional insufficiency, gastrointestinal nematodes are major constraints to kids' survival (Knox and Steel, 1996). Protein and energy must be adequately provided for optimum growth and reproductive performance in young animals.

Weight gains by goats is sensitive to protein and energy content provided in their diets (Coop *et al.,* 1995; Turner *et al.,* 2005; Soto-Navarro *et al.,* 2006). Therefore, feeding kids on a low and poor nutritional plane will not allow for effective immune response against parasitism since all scarce nutrient resources will be competed for between the functions of the host.

2.6.3 Effect of nutrition

Goats living in harsh environments are able to adjust to such areas through maintenance of a low body mass, low metabolic and water requirement to enable them survive even after long periods of severe limited food availability (Silanikove, 2000). However, when such goats become parasitized by helminths, the demand for limited feed resources will be competed for between maintenance, growth, repair of gastrointestinal pathology and immunological responses (Coop *et al.*, 1995). The effect of improved nutrition on reduced pathology of gastrointestinal helminths in livestock has been reported (Knox and Steel, 1996; Kahn *et al.*, 2003). It has been proposed that the host will always give priority to the function of growth, pregnancy and lactation over expansion of immunity. Therefore, improved nutrition may affect the extent to which the immune system will function during these phases.

There is a relationship between stocking density and feed availability on pastures, the higher the stocking density the lower the feed available on pasture. Thamsborg *et al.* (1998) reported that when the stocking rate was increased during grazing, the resultant effect was high parasitaemia, evident by high faecal egg count, anaemia, reduction in weight gains, poor carcass value. The increase in parasites may probably be due to more animals on limited feed resources or high concentration of animals and consequently more contamination of pasture and water. Wallace *et al.* (1995) reported that lambs supplemented with soyabeans were able to withstand the effects of

trickle infection with L_3 *H. contortus* larva while those on basal diet alone became infected with higher faecal egg counts, even though there was no difference in the total number of worms between the supplemented and control lambs. It was observed that supplemented lambs had decreased number of female worms, which were short and gravid with fewer eggs. The lambs on the control basal diet showed more signs of anaemia, hypoproteinaemia, hypoalbuminaemia than those on supplemented diet. In a similar study with sheep using the same *Haemonchus spp,* Wallace *et al.,* (1995) observed that those sheep on supplemented diet had higher weight gains, heavier lean carcass, higher Packed Cell Volume (PCV) than those on basal diet (Abbott *et al.*, 1986; Haile *et al.,* 2002).

One of the most limiting nutrients in parasitized livestock is protein, because protein is one of the ingredients along with vitamins and minerals that can influence humoral and cellular inflammatory responses of the host (Fivaz *et al.,* 1993; Datta *et al.,* 1999), since protein provides the amino acids that form enzymes acting on different pathways. Coop *et al.* (1995) in an attempt to study the effect of protein in development of immunity against *Ostergia circumcincta* supplied by-pass protein casein to a group of lambs while the other group acted as control. Casein-supplemented lamb had fewer challenge worms, lower L_4 larvae in the abomasum, higher mast-cells, i.e. responsible for expulsion of gastrointestinal nematodes.

Also the casein-supplemented lambs had enough protein to efficiently develop immune response as well as for growth. Forages containing condensed tannins have been known to adversely affect intake of forages (Kaitho *et al.,* 1998) but when fed to parasitized animals, these forages containing high condensed tannins reduced parasitism by reducing total faecal eggs output and

faecal eggs count than those parasitized animals fed forages containing low condensed tannins (Min *et al.,* 2003; Neizen *et al.,* 1995).

2.6.4 Effect of acquired immunity

Acquired immunity is the ability of the host to obtain protection, through exposure to slow challenge, against infective organism (Emery *et al.,* 2000). Ruminants have been observed to express good protection against helminths that are prevalent in their environment. Ruminants are constantly exposed to infective nematode larvae but many of the infective organisms are killed by the host's non-specific defenses. Infective stages that attempt to enter via the mouth or through the skin (Rahman and Collins, 1990) are challenged by non-specific defense mechanisms. This includes physical and chemical barriers provided by natural resistance. Helminths have been able to evade these defense mechanisms to reach maturity; therefore the number of helminths present at any given time is a representation of the balance between the rate of infection and the efficiency of the defense cells.

With continuous challenge, the animal is able to acquire immunity to helminths. To demonstrate this phenomenom, Chiejina *et al.* (2002) were able to show that the Nigerian West African Dwarf (WAD) goats have the ability to resist the effects of its native strain of *Haemonchus contortus* with wide individual variability. This means that the WAD has over the years been able to withstand the pathogenic effects of the local *H. contortus* strain, although the level of resistance varied between individual goats. This therefore lends credence to the need for individual selection to obtain a group of WAD that may possess a good measure of resistance for breeding purposes.

2.6.5 Effect of genetics

The ability of the helminths to establish a disease will be dependent on its ability to destroy or eliminate the host's specific defenses. Although there may be species resistance to particular parasites, most of the resistance has been shown to be influenced by breeds and individual variability (Matika *et al.,* 2003). Various breeds of sheep, goats and cattle have demonstrated varying levels of susceptibility to helminthosis. Waweru *et al.* (1999) demonstrated that the Dorper and Red Masai breeds of lamb showed different parasitological responses to *Fasciola gigantica;* and on the basis of egg counts and clinical pathology the Dorper lambs were more susceptible to fascioliasis than the Red Masai lambs. Similarly, Mugambi *et al.* (1997) also showed evidence that the Dorper sheep were more susceptible to *Haemonchus contortus* infection than the Red Masai sheep (Preston and Allonby 1979ab). The Red Masai sheep proved to be more resistant to natural *H. contortus* infection than the Black-headed Somali, Dorper and Romney breeds of sheep. Following artificial infection with 10,000 *H. contortus* L_3, the Red Masai sheep maintained a low egg output and a higher PCV than the other breeds of sheep.

Further works which compared different genotypes of sheep and the susceptibility to haemonchosis showed that even though there was breed variation, individual variation within genotype differences was also present, making it possible to select within breed to obtain resistant flock against helminths that are of environmental significance (Burke and Miller, 2004). Chauhan *et al.* (2003) investigated the Barbari and Jamunapari breeds of Indian goats and reported that following infection with *H contortus* there was no significant breed difference between the Barbari and Jamunapari goats in faecal egg count (FEC) or packed cell volume

(PCV) at 3, 6, and 9 months of age. The Jamunapari male kids had significantly higher FEC than the female kids at 6 months of age, but the female Barbari kids had higher FEC than their male counterparts at 9 months. Age had a significant effect on FEC in both breeds. The FEC increased from 3 months. Similarly, Baker *et al.* (1998) reported that the Small East African goat was more resistant to GI nematode infection than the Galla breed because they showed significantly lower FEC and higher PCV, with a marked and persistent peri-parturient rise in FEC in the Galla than the Small East African goat. The breed difference was particularly marked during lactation since during the lactating period there is a higher demand on maternal reserves leaving minimal for defense.

2.6.6 Haemonchosis:

2.6.6.1 Aetiology

Haemonchus contortus (Plate 1) belongs to the class, Secernentea; Subclass, Rhabditia;

Order, strongylida; Superfamily, Trichostrongyloidea; Family, Trichostrongylidae (Soulsby, 1982). It is commonly called the barber's pole worm, wire worm and, it is found in the abomasums of sheep, goats, cattle and wild ruminants (Haroun *et al.,* 1996; Scott *et al.*, 1998). *Haemonchus contortus* is widely distributed but it's more prevalent in warm moist regions than in cold dry areas (Machen *et al.,* 2006). The nematodes found within the same family include the following genera *Trichostrongylus, Cooperia, Ostertagia* and *Nematodirus.* However, *Trichostrongylus* and *Haemonchus* remain the most important genera affecting ruminants, with *Haemonchus* spp recording higher prevalence rate and pathogenic consequences than *Trichostrongylus* in Nigeria in small ruminants (Fabiyi, 1970; Ogunsusi, 1979; Nwosu, 1996; Chiejina, 1998).

Haemonchus placei is the other species within this genus that affects mainly cattle. Members of the family are known to cause a syndrome called parasitic gastroenteritis (PGE), which is characterized by inappetance, anorexia, anaemia, emaciation, diarrhea and reduced weight gain.

Plate 1: Adult female worm of *Haemonchus contortus* X 200um

2.6.6.1 Morphological characteristics of the *Haemonchus contortus*

The small buccal capsule bears a curved dorsal tooth called the lancet, (plate 2) with two prominent lateral spike-like cervical papillae near the junction of the first and second quarters of the esophagus (Soulbsy 1982; Lichtenfels, Pilitt and Hoberg, 1994). The males are 10 to 20 mm and the females 18 to 30 mm long. The male bursa (plate 3) has long lateral lobes and slender rays with a flap-like dorsal lobe located asymmetrically near the base of the left lateral lobe. The spicules are 450 to 500 um long, each with a terminal barb; the gubernaculum is navicular (Jacquiet *et al.,* 1998). In the female worm the white uteri and the ovaries wind around the red blood-filled intestine giving a twisted or barber pole appearance (Lichtenfels *et al.,* 1994). Usually, the vulva is covered by an anterior thumb-like flap which may be reduced to a mere knob in some individuals. The eggs are about 70 to 85 um long by 41 to 44 um wide, and in the early stages of cleavage when laid.

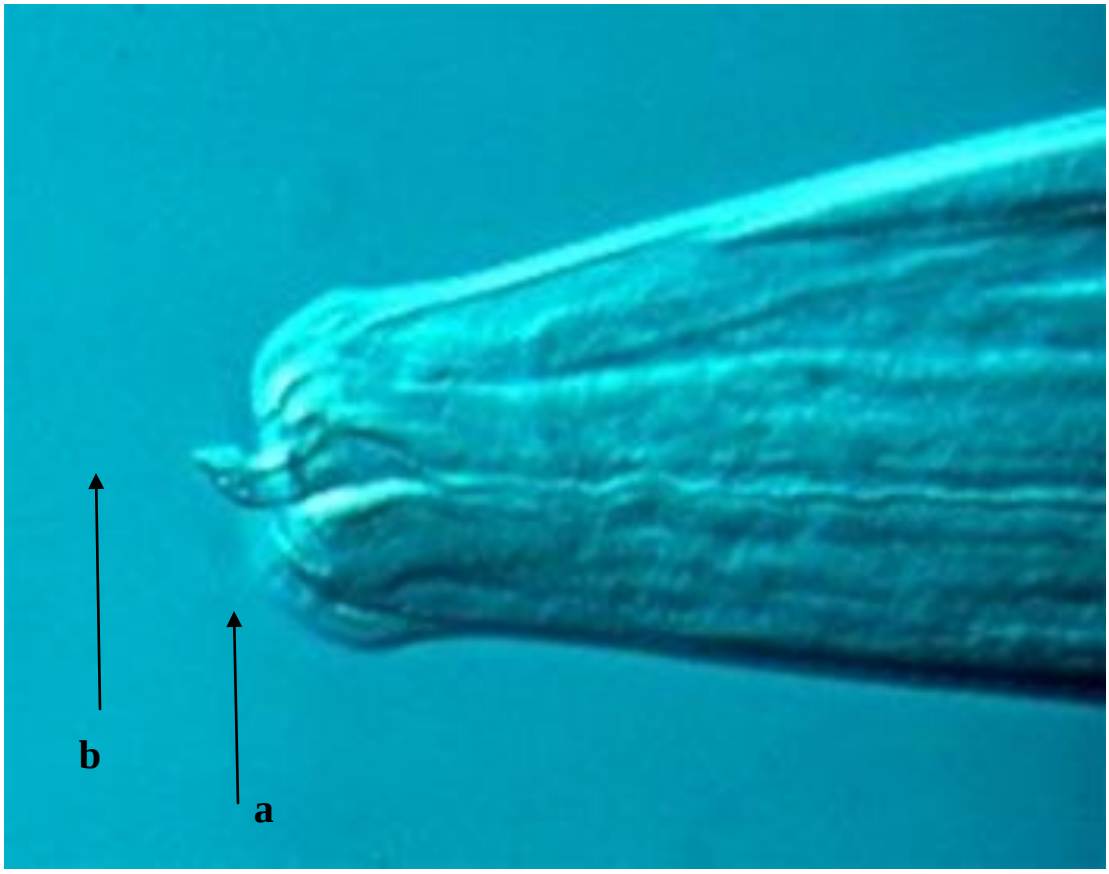

Plate 2: Anterior region of *H. contortus* showing the buccal capsule (a) and the lancet (b) (X 200um)

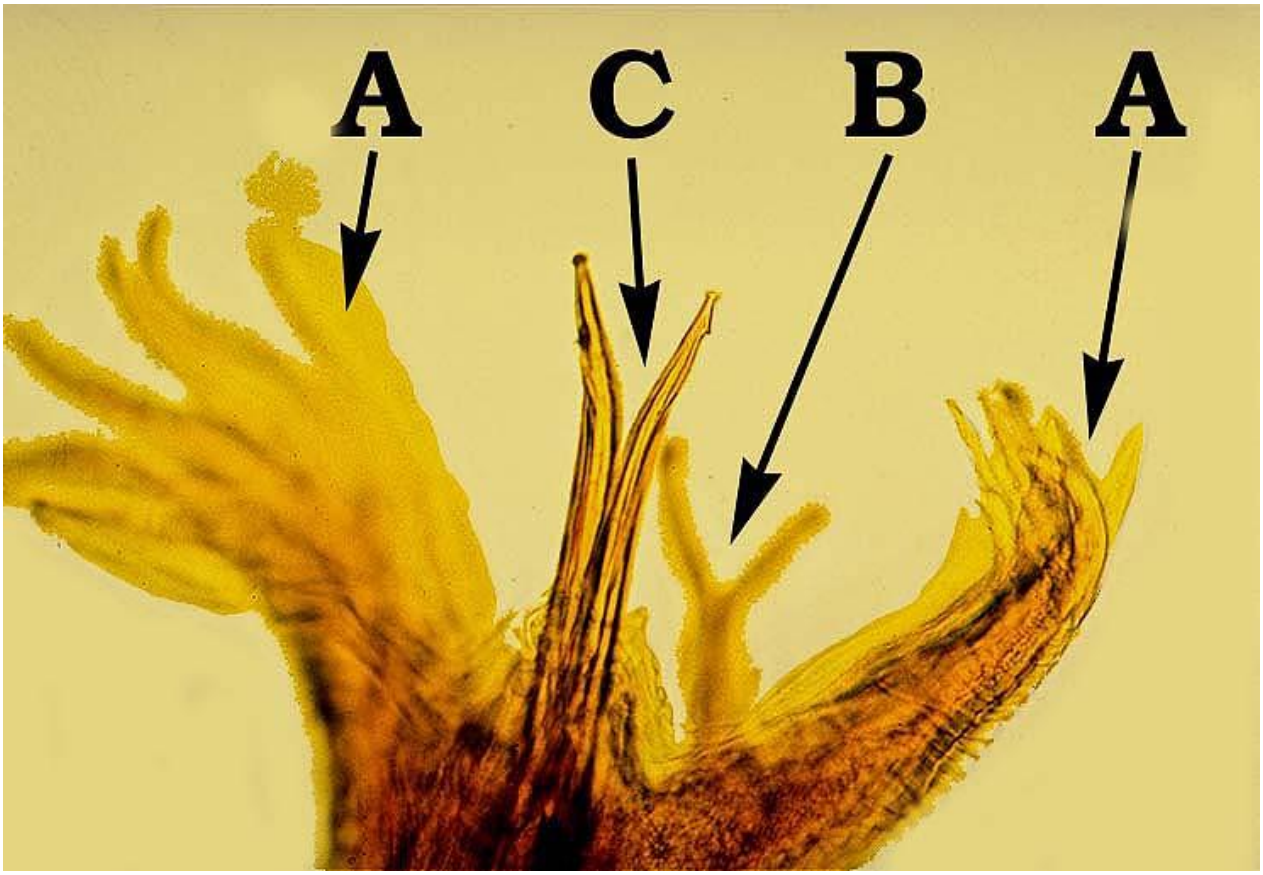

Plate 3: Corpulatory bursa of male *H. contortus.* Note the lateral (A), dorsal (B) rays and the spicules (C) X 200um

2.6.6.2 Life cycle and transmission

The life cycle from egg to mature adult lasts for 17-21 days. No intermediate host is required. Adult male and female worms live in the abomasum (true stomach) of ruminant where they lay un-embryonated eggs (Bowman, 1999). Female worms can deposit 5,000 to 10,000 eggs per day which are passed out of the host with the faeces (Bowman, 1999). After a day or two, the first stage larva (L_1) hatches and these larvae feed on micro-organisms in the faeces while developing and moulting into second larva (L_2) and then L_3. The L_3 (plate 4) retains the cuticle of the L_2 as its sheath and doesn't feed but is the infective stage for the vertebrate host.

Environmental factors will influence development of the larva on pasture as well as their distribution on to the herbage (Stromberg, 1997). Under optimal conditions of moisture and temperature, eggs reach infective stage by 5-6 days. Development varies from one geographical region to another; the rate of development increases with increasing temperature, but reaching a maximum of 40^oC where larvae begin to die. The ideal temperature for larval development is between 18 and 26^0C but some development still continues at lower temperature (Mansfield *et al.,* 1997). To demonstrate this phenomenon, Troell *et al.,* (2005) studied the effects of inoculating cold-stored (5^0C for 9 months) infective L_3 and newly hatched larvae on lambs and found that the extent of establishment of the parasite did not differ between storage methods, with varying infection rates of between 43 and 72% irrespective of the method of storage. Similarly, *Capitini, et. al.,* (1990) did not observe any significant difference between natural or artificial conditioning of both pre-infective and infective stages of *Haemonchus contortus*. The ideal humidity for survival and development of larva ranges between 80-100%, with shade also

playing important role for successful development. It is usually difficult for larvae to survive without moisture, because moisture must be present to prevent desiccation and death (Jacquiet *et al.*, 1997). Moisture has an effect on the motility of the larva; therefore if an environment is dry, movement into the surrounding herbage may be impossible, forcing the larva to move into the soil or the faecal pat. Too much moisture like heavy rain may also disrupt the pat creating a run-off effect (Agunloye *et al.*, 2002).

The ruminant is infected following ingestion of pasture harbouring infective larvae, and exsheathment occurs in the anterior rumen. The young worms enter the abomasum, penetrating the mucosa before moulting to L_4 juveniles. Upon their migration to the para-mucosal lumen of the abomasum, the L_4 begin to feed and moult to adults. The pre-patent period varies depending on the species of but generally it lasts between 31/2-4 weeks (Karin C. 2004). In favourable conditions, the adult worms continue producing eggs to contaminate the pastures, but when the conditions are not favourable the larvae undergoes arrested development or hypobiosis. Hypobiosis, the ability to slow down process and remain in a dormant state is an important adaptation of *Haemonchus contortus* as well as other trichostrongylids to survive adverse periods in the environment (Connan, 1975). The infective larvae undergo hypobiosis when they are acquired during the late rainy season (Waller and Thomas 1975; Gatongi *et al.*, 1998).

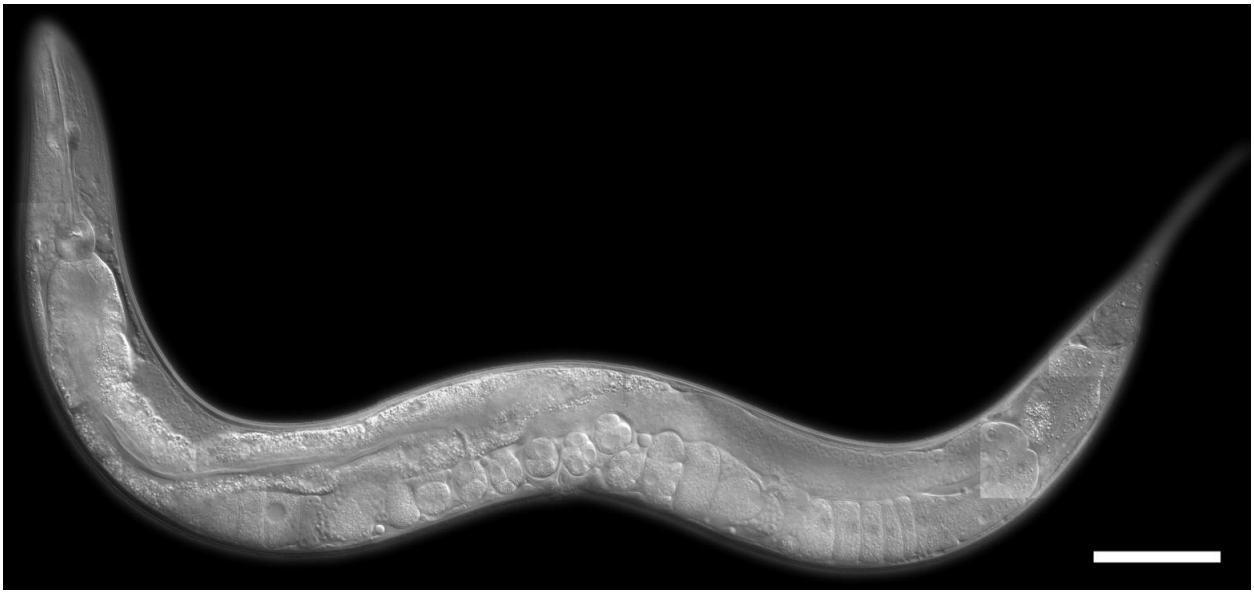

Plate 4: ***Haemonchus contortus*** **third larval stage X 200um**

2.6.6.3 Prevalence of *Haemonchus contortus*

Although numerous gastrointestinal nematodes are present in ruminants, *Haemonchus contortus* presents the greatest production and reproduction problems (Fagbemi and Dipeolu, 1982; Kamst *et al.,* 1983; Anene *et al.,* 1994; Mbaria *et al.,* 1995; Papadopoulos *et al.,* 2003). The prevalence rates of *Haemonchus contortus* in small ruminants in Nigeria is greater than 50%. In an epidemiological study of helminthosis in small ruminants kept under traditional husbandry system in Nigeria, Fakae (1990) observed that infections due to *H. contortus* was as high as 87.1% for a 12-month period, with the highest prevalence during the cropping seasons when the goats are tethered. Nwosu *et al.* (1996) also recorded a 90% prevalence rate for *H. contortus,* when intestinal and faecal samples were examined in Red Sokoto goats slaughtered in Ibadan abattoir, young animals having higher worm counts than adult animals. Umoh *et. al.* (1982) reported that strongyle infections were the most common gastrointestinal parasites in Zaria accounting for about 34.6% prevalence rate. Fabiyi (1970) reported a prevalence rate of 80% in goats in Zaria area.

2.6.6.4 Pathogenesis of *Haemonchosis*

Gastrointestinal parasitism in growing animals is usually associated with impairment of protein metabolism (Suttle, 1994). Invading nematodes acquire nutrients by penetrating the host tissue barriers, causing damage to the gastrointestinal mucosal that result in increased plasma leakage, leading to endogenous protein loss into the lumen (Kyriazakis *et al.,* 1994), which in combination with anorexia has been suggested to be the main cause of production losses in growing animals (Niezen *et al.,* 2005).

Infective larvae that invade the abomasum cause physical and physiological changes in the gastric mucosa. The abomasal nematodes which feed on blood like *H. contortus, Ostertagia circumunata, and Trichostrongylus vitrinus* secrete a variety of protease enzymes, anti-coagulants, haemaglobinases, albuminases and peptidase, which are responsible for peptide degradation prior to absorptions of these nutrients (Hadas and Stankiewicz, 1996; Hadaś and Stankiewicz, 1998; Redmond and Windam, 2005). These blood-feeding nematodes may also release carbohydrate and lipid hydrolases (Knox, 1994) and also increase plasma pepsinogen concentration (Scott *et al.,* 1999). Similarly, abomasal nematode infection induces efflux of sodium (Na) into the lumen but this is quickly corrected by re-absorption in the distal sites of the gastrointestinal tract (Suttle, 1994). However where there is a combined abomasal and intestinal infection, sodium becomes deficient in parasitized animals. (Suttle, 1994). In mixed infections with other parasites other than helminths, as in mixed protozoan and nematode infections there is usually increase in severity of the pathogenicity (Agyei *et al.,* 2004; Chiejina *et al.* 2003) with resultant high endogenous protein loss. This will increase the competitive demand for available digested nutrients between growth, repair of gastrointestinal pathology, pregnancy, lactation and immune response. The growing young animals will respond to the first two demands at the expense of immunity (Coop *et al.,* 1995). Likewise, female animals that are pregnant or lactating will respond to these demands at the expense of immune reaction (Baker *et al.,* 1998). The pathology can be more pronounced in parasitized animals that are malnourished; and improving the nutrition of these animals will always lead to better resilience (Wallace *et. al.*, 1998),

2.6.6.5 Clinical symptoms of *Haemonchosis*

In hyperacute haemonchosis, sudden deaths in a flock of previously healthy sheep and goats are seen. This syndrome results from ingestion of large numbers of infective larvae by sheep grazing on a heavily contaminated pasture. It often follows a period of warm, wet weather during which massive numbers of *H. contortus* eggs develop rapidly to infective stages (Dimander, 2003). At necropsy, large numbers of worms are found in the abomasum - anywhere from 20,000 to as many as 50,000 have been reported by Durie and Elek (1966)

In acute haemonchosis**,** grazing sheep develop a sudden onset anemia, the PCV drops initially signaling exhaustion of the erythropoietic system and in chronic disease there is bottle jaw and emaciation. At necropsy, these animals will be pale and edematous and longitudinal sections of the long bones will show expansion of red marrow into the medullary cavity. Anywhere from 2,000 to 20,000 worms may be found and the abomasal contents will be brown due to the presence of blood. Hemorrhagic lesions will usually be present on the abomasal mucosa (Coadwell and Ward, 1975; Stear *et al.,* 1995.). Vatta *et al.* (2001) in testing for clinical anaemia caused by *H. contortus* in goats used the colour chart developed for sheep based on five colour categories depicting varying degrees of anaemia using the mucous membrane of the eye. The goats were scored from severe anaemia (pale), anaemia to non-anaemia (red). Using the colour chart, goats with pale mucous membranes of animal were classified as requiring anti-helminth treatment and the test had a sensitivity of between 76-85%. Chronic haemonchosis in a sheep flock usually results from a combination of infections with small numbers of worms and poor nutrition that persist for a prolonged period of time (several weeks or months). Infected

sheep suffer a chronic daily loss of small amounts of blood but this loss is exacerbated by a diet poor in protein. As a result, these animals are unable to replace all their lost serum proteins from their deficient diet. Consequently, they lose weight as they mobilize muscle proteins to provide the amino acids necessary to synthesize vitally important proteins such as plasma proteins and haemoglobin (Agyei, 2003). The loss of endogenous protein may lead to the swelling of the jaw referred to as "*bottle jaw"* (Luginbuhl, 1998). Due to inappetence others symptoms may include loss of weight, unthrifti-ness and marked decrease in milk production (Idris *et al.* 1982).

2.6.6.6 Effect of nutrition on pathogenesis of *H. contortus*

Growing lambs between 3 to 6 months acquire immunity more slowly than animals that are 8 months and above. It therefore suggests that *H. contortus* can greatly affect the growth performance of young animals (Pralomkarn *e. al.,* 1997**)**. To determine the rate of development of immunity and influence of supplement to *O. circumcincta* infection in growing lambs Coop *et. al.* (1995) continuously infused sodium casienate into the abomasum of both infected and control lambs. Although all animals received a complete ration, those on infused casienate had lower worms recovered and accelerated development of immunity than the un-supplemented infected lambs with out any significant difference between the mean of serum total protein or albumin concentration. Protein rather than caloric content of a diet is important for the immune development in livestock. Abbot *et al.* (1985) conducted a study to examine the influence of low (88g CP Kg^{-1} DM) (LP) and high (70g CP kg $^{-1}$DM) 9HP) protein diets on the pathogenesis of *H. contortus* in the Finn dorset and Scottish black face lambs and showed that in the Scottish blackface lambs dietary protein did not significantly influence the establishment of *H. contortus.* Meanwhile dietary protein played a significant role in the Finn Dorset lambs because lambs on

the low protein diet had higher faecal egg out than those on the higher protein diet. Generally lambs on the higher protein group had about 2kg live weight gain advantage over those on the lower protein group; however weight loss was recorded between weeks 4 and 8. Macrocytic anaemia was observed in both dietary groups of Finn dorset lambs. Mean PCV values fell to minimum levels 4 to 5 weeks post infection (PI), although the differences in the severity of the anaemia between the groups was not statistically significant. The infected Scottish blackface lambs, showed moderate macrocytic anaemia, hypoproteinaemia, the mean PCV fell to minimum of 0.29lt/lires, 4 week PI in the high protein group while the minimum level of 0.25 lt / litre occurred at week 8 PI in the low protein group. In the control, there was slight anaemia between 6 and 8 weeks in the Scottish black face.

The result shows that the Finn Dorset developed severe anaemia, hypoproteinaemia, hypoalbuminaemia while these were less severe in the Scottish blackface lamb. It concludes that dietary protein does not significantly influence the establishment or pathogenicity of infection with *H. contortus*, in Scottish black face lambs while in the Finn Dorset lambs dietary protein has a transient effect on parasite establishment. In Kenya, Mugambi *et al. (*1997) studied the resistance of the dorper and red masai lambs to trickle *H. contortus* infection, and reported that the controls were mostly negative throughout the experiment but the Red Masai lambs reached maximum count of 15,300 epg at week 8 PI whereas the Dorper recorded their first peak of 23,000 epg also at week 8 PI, and the second and higher peak at week 11. The overall difference was significant for breed, individual and daily variations. Mean PCV decrease from 29 and 31 per cent in the Dorper and Red Masai lambs in week 1 to minimum of 17% in the Dorpers in week 12 and 22% in the Red Masai in week 10.

Thereafter Packed Cell Volume increased gradually to the end of the experiment. Total serum concentration decreased in infected groups from 58.1g/litre in week 4 to 47.4g/litre for Dorpers and from 60.5 to 51.3g/litre for the Red Masai but remained constant in the control groups. In conclusion the Dorpers had higher faecal egg count, low Packed Cell Volume, severe hypoproteinaemia, and similar weight changes than the Red Masai lambs. It can be deduced that the Red Masai lambs are more resistant than the Dorper lambs to trickle *H. Contortu*s infection on the basis of faecal egg counts, Packed Cell Volume, eosinophil counts, total serum protein concentration.

Thomsborg *et al.* (1998) demonstrated that sheep on high stocking rate had higher reduced weight gains, and depressed serum albumin than lambs on lower stocking rate. Magona and Musisi, (2002) reported that grazing system, season and agro climatic zone had significant influence on intensity of gastrointestinal nematode strongylosis infection in goats; while age of the goats did not have any significant effect.

2.6.6.7 Effect of *H. contortus* on milk production

Helminth infections, species diversity within community, species number, intensity of infection and antihelmintic resistance are factors that influence dairy production world-wide (Silvestre *et al.,* 2000). In dairy goats several studies have indicated that high-producing and first lactating goats within a flock are less resistant and resilient to nematode infection than *does* from the same flock with low level of milk production.

Papadopoulous *et al.* (2003) showed that parasitic burden was significantly higher in dairy sheep than in dairy goats, and that faecal egg counts was affected by month of the year with

Haemonchus spp being amongst the most important genera affecting dairy goats and sheep in Greece. The differences in resistance and resilience may be related to the level of infection and grass intake. The feed requirements for high producing goats are higher than for low producing goats during lactation. Consequently high producing animal will eat more than the low producers under natural conditions, possibly ingesting more infective larvae. Etter *et al.* (2000) reported that the differences in response to infection in dairy goats as well as the level of milk production are dependent on both nutritional and generic factors. The differences between the high-producers (HP) and low-producers (LP) in terms of parasitic challenge was noticed at the beginning of the lactation when the requirement by the HP may not be met by the routine ration, therefore requiring supplementation. Hoste and Charteir (1993) and Charteir and Hoste (1997) showed that when challenged with nematode, the high producing (HP) goats had higher egg excreted than the low producing (LP) goats, but when dietary protein was included in their diets, the HP goats exhibited lower egg output especially when supplemented diet was 125% as against the normal protein content of 106%.

Etter *et al.* (2000) showed that there was no difference in the egg excretion, worm counts, and blood eosinophils of high producing and low producing goats infected with *T. columbriformis*. The culled dairy goats were selected for the divergence in their previous milk production but they still had the same response to *T. colubriformis* infection. Egg excretion peaked in week 5 of infection and decreased in week 6 and the inorganic phosphate values were restored by week 6 post infection, showing a positive response by the animals. Therefore the similarities in the response to *T. colubriformis* infection observed in the two groups of animals may be related to differences in physiological and nutritional status of the animal rather than the fixed genetic

characteristics. Therefore control of nematode parasites during lactation may improve milk yield in dairy animals.

In a review article of over 80 experiments in dairy cows. Gross *et. al.* (1999), reported that about 80% of the experiments had an increase in milk production and milk fat after antihelmintic treatment. Hoste, *et. al.* (2005) showed that dairy goats fed tannin-containing hay (sain foin) had lower egg accounts and that the consumption of sainfoin was not associated with any detrimental consequences of both milk yield and quality.

2.6.6.8 Host response

Helminths that live at mucosal sites such as those in the gastrointestinal tract can be considered not to be truly living within the organisms (Mulcahy *et al.,* 2004). *H. contortus* infects the abomasums of goats and sheep. The third larva stage is the infective stage which moults into the fourth larva stage in the crypts of the abomasums (Jacobs, *et. al.* 1995). The adult parasite inhabits the abomasum, where it's only attached through its mouth parts. Therefore the immune system of the goat is only exposed to the antigen of *H. contortus* when L_3 and L_4 are in the abomasum crypts and to secretion/excretions released by adult (Ruiz *et al.,* 2004) during feeding on blood capillaries in abomasal wall (Tabouret *et al.,* 2001). This restricted exposure of the parasite may be the reasons why repeated larval infections are required to establish protective immunity. The host immune responses to helminths can be achieved either through non-specific (innate) or acquired (adaptive) immunity (Brake, 2003).

2.6.6.8.1 Innate Immunity

The innate immunity is age-related and begins usually as a response to tissue damage. Although innate immunity is usually weak in helminth infections, the skin and lung and the gastrointestinal

tract (GIT) are equipped with physical and chemical barriers to infective organisms, as a first line of defense (Decker *et al.,* 2002; Kanobana, 2003).

For parasitic infection, the complement activation provides the next line of defense. The complement C_3 cleaves to plasma to produce C_3b, which binds and stabilizes in the parasite surface to form a C_3 convertase. This convertase activates the terminal C5 – C9 complement responsible for lysing the parasite (Hoerauf and Steel, 2004; Hadas and Stankiewicz, 1996). The host causes release of the macrophages and neutrophilic leukocytes to infection sites; by means of their receptors, these cells are able to recognize foreign organisms thereby ingesting them. Due to the infestation of the parasites the macrophages secrete cytokines, which include interlukin – 1 (IL-1), IL – 6, IL-8, IL-12 and tumor necrosis factor (TNF) (Ustun *et al.*, 2004). These factors recruit phagocytes, circulating neutrophils at the site of infection. These phagocytes release other proteins like oxygen radicals, peroxides, nitric oxide, prostaglandins etc. and interferon. Once the helminths have survived the weak innate immunity, the acquired immunity, now comes into play.

2.6.6.8.2 Acquired or adaptive immunity

Since the innate immunity is considered to be a weak response to helminths infection, the acquired immunity is the most protective mechanism against helminths. Acquired immunity is mediated by the humoral and cellular immune systems. Helminths are the classic inducers of Thymus-helper2 (Th2) responses. Although much is known about the pathways of Thymus-helper1 (Th1) response induction via the dendritic cell (DC), the mechanisms that drive Th2 responses remain unclear. One hypothesis has been that Th2 responses occur by default in the

absence of DC activation. However, recent studies have shown that helminths products are able to actively mature DCs and affect the expression of surface markers and cytokines (Claerebout and Vercuysse, 2000).

Studies with rodents infected with *Trichinella spiralis*, *Heligosomoides polygyrus*, *Nippostrongyleus brasiliensis*, and *Trichuris muris* have provided considerable information about immune mechanisms that protect against parasitic gastrointestinal nematodes. Ustun *et al.,* (2004) stated that, $CD4^+$ T cells (critical for host protection); IL-12 and IFN-γ (inhibit protective immunity); IL-4 (required for host protection, as well as limiting the severity of infection, or induction of redundant protective mechanisms); and some cytokines are stereotypically produced in response to gastrointestinal nematode infections. Similarly, Faulkner *et al.* (1998) upon infection with the cecum-dwelling nematode *Trichuris muris*, found that majority of the in-bred strains of mice launched a Th2-type immune response and in doing so expelled the parasites before patency, but in contrast, there were a few mouse strains which developed a non-protective Th1-type response resulting in a chronic infection and the presence of adult worms. Of the Th2 cytokines known to be associated with the resistant phenotype were interleukin-4 [IL-4], IL-5, IL-9, and IL-13, although little is known about the contribution of IL-9 towards the protective immune response (Adrian and Pearlman, 1998). In this study Adrian and Pearlman, (1998) demonstrated that IL-9 is expressed early during the Th2-type response and that its elevation *in vivo* enhanced intestinal mastocytosis and the production of both the immunoglobulin E (IgE) and IgG1 isotypes. In addition, elevated IL-9 levels in vivo facilitated the loss of *T. muris* from the intestine (Balic *et al*., 2002).

It is now clear that when an intestinal helminth infection takes place the immune system generates a strong Th2-mediated response, which regulates a variety of responses characteristic of helminth infections such as eosinophilia, intestinal mastocytosis and elevated IgE production. Eosinophils or 'eosinophilic granulocytes' normally comprise only a small fraction (1–5%) of circulating leukocytes (Grencis, 1997). Eosinophils develop in the bone marrow and are released subsequently at a low rate into the circulation. They are terminally differentiated cells that do not appear to multiply after leaving the bone marrow; their half-life in blood is about 18 hours. (Meeusen and Balic, 2000).

Most of the eosinophil population is found in the tissues, predominantly those at the surfaces of the body that interact with the external environment, like the skin and mucosal surfaces of the gut, respiratory and reproductive systems. Eosinophils arise in the bone marrow from haematopoietic CD341 precursor cells 4 (Behm and Ovington, 2000). The early stages of their differentiation are controlled by the cytokines (granulocyte–macrophage colony-stimulating factor- G-CSF and interleukin 3-IL-3), which also controls the development of other granulocytes such as neutrophils, basophils and mast cells. The later stages of differentiation and maturation of most of the eosinophil population are controlled by the cytokine IL-5, which is produced by activation of T cells and mast cells. It has been shown that IL-5, found at high levels in helminth-infected hosts during the T-helper type 2 (Th2) cytokine-biased immune response, appears to be important in mucosal immune responses and is responsible for helminth-induced eosinophilia. (Behm and Ovington, 2000). The IL-5 has the primary function of defense against organisms that are too large to be phagocytosed, particularly parasitic helminths. This is evident by the fact that 1) eosinophils degranulate on to and can kill helminths *in vitro* in the presence of

antibody and/or complement; (2) they move from the blood and aggregate in the locality of helminths *in vivo*; (3) large numbers of eosinophils are often seen in close association with both intact and damaged helminths *in vivo*; and (4) the eosinophils clearly degranulate in the vicinity of, or the surfaces of, helminths. For example, it has been observed that the resistance of inbred strains of mice to infections with *Taenia taeniaeformis*, *Trichuris muris* and *Nippostrongylus brasiliensis* is positively correlated with their capacity to generate tissue eosinophilia after infection. In addition, within one inbred strain of mice, the variable worm burdens of individual mice for *T. muris* correlated negatively with intestinal eosinophil levels. Also, in out-bred mice reared selectively as high or low immune responders to infection with *Heligosomoides polygyrus*, immunity was strongly correlated with peripheral blood eosinophil counts after primary and secondary infections (Behm and Ovington, 2000). Adams and Colditz (1991) infused antigens in the mammary gland of non – lactating goats and reported that the antigen elicited larger eosinophil-rich exudates with increased number of macrophages and lymphocytes in immuned compared to un-immuned sheep. In addition, antigens from infective larvae of *H. contortus* elicited cellular exudates potently than antigens from adult worms.

Adult helminth infections are not normally associated with eosinophilia, but induce mast cell hyperplasia, and cause changes in mucus production in the gastrointestinal tract. Mast cells in particular have been associated with expulsion of adult worms and rapid rejection of incoming larvae, before they can establish in the gastrointestinal tissues (Adams and Colditz, 1991). However, several studies (Jasmer and McGuire, 1991; Smith *et al.,* 1993; Lacroux *et al.,* 2006) with gastrointestinal nematode infections of sheep have suggested that two separate mechanisms might be active in rejection of infective larvae of gastrointestinal nematodes: 1) mast cells and

globule leukocytes can cause expulsion of larvae before they infect the tissue (rapid expulsion); 2) delayed response, might be active against larvae that succeed in penetrating the gastrointestinal tissues (delayed rejection). Recent experiment (Schallig, 2000) with the sheep gastrointestinal nematode, *Haemonchus contortus*, has shown that when sheep were challenged with infective larvae several weeks after elimination of adult infections, mast cell numbers were decreased, and challenged larvae were found within the tissues. In this case, eosinophils were recruited specifically to the site where larval penetration occurs and larval damage could be detected. Even when no major increase in general tissue eosinophilia was apparent, eosinophils were still specifically concentrated around L_3 larvae within 24 hours after infection. These findings suggest that, in the absence of the rapid expulsion mechanism induced by the recent or existing presence of adult worms, infective larvae of gastrointestinal nematodes, like those from skin-penetrating nematodes, may be effectively killed by eosinophils.

Balic *et al.* (2002) demonstrated the significance of localized immunity of *H. contortus* by challenging sheep with 4000 L3 of *H. contortus*, drenching them with levamisole, and then maintaining them worm-free for 3 months before challenging them with 50,0000 L3 *H. contortus*. The changes that accompanied the presence of larvae in tissues of challenged sheep included increase in the relative percentage of γδ TCR^+ T cells, B cells as well as increase in the proportion of CD^{4+} T cells. In the abomasal mucosa, there was an increase in the number of infiltrating CD_4^+, γδ TCR^+ T cells and B cells (Perez *et al.*, 2003). These changes were observed 3 days post infection, and these levels were further increased by the 5^{th} day. Meanwhile, in previously infected sheep, these changes where observed 3 days post infection. The increase in percentage of CD4+ T cells (MHC II) in the local lymph node was found in both primary and

secondary infected sheep, while the increase in γδ T cells, B cells as well as increase in the CD4+, CD25+ T cell, in the abomasal lymph makes were only observed in the secondary infection.

It is obvious that the T cells along with their receptors are usually associated with the variable region of the MHC molecules, while the CD_4 or CD_8 bind to the constant region of the MHC molecule. In most reactions, the CD_3 – complex is usually modulated by the CD_{40} and CD_{40} ligand or B7 and CD28. These stimulate the T helper1 subtypes responsible for delayed type of hypersensitivity or theTh2 which are important in allergic and humoral immune responses (Schallig, 2000). In general, helminth infections are associated with dominant Th2-mediated immune responses (Mountford and Pearlman, 1980), characterized by eosinophilia, intestinal mastocytosis and elevated IgE production. Therefore depending on how fast these cellular immune responses are generated, the parasite can be rapidly rejected before it gets to its tissues niches, or delayed where the humoral immunity is involved. Even though response due to *H. contortus* is limited due to its minimal exposure to host tissues, studies has shown than the host produces serum antibody against helminths (Abrahams – Saudi *et al.*, 2005).

2.6.6.8.3 Humoral immunity

The high prevalence of helminth infection in endemic areas, the ability of animals to remain infected for many years and the decline in the intensity of infection as animal ages suggests that protective immunity following challenge may be responsible for the host defenses (Kyriazakis *et al.*, 1996). The main antibodies that block enzyme release by worms are the IgG, IgE and IgM, which binds to surface antigen and together with the complement (Adams, 1988), interfere with

its penetration and feeding in tissues. Intestinal worms are usually dislodged by both structural and physiological changes, but the IgE mediate hypersensitivity reaction along with mast cells, basophils which may contribute to this process of destruction of the helminths. To evaluate the humoral responses following local immunization with surface antigen of *H. contortus*, Jacobs *et al.,* (1995) inoculated nine-month old lambs three times with surface antigen administered either peripherally or into the abomasums. Challenged with L_3 of *H contortus* 2 and 5 weeks after the first inoculation showed higher increase in the levels of antibody in sheep given surface antigen than in the controls. Similarly, Charley-Poulin, *et. al.*, (1984) showed slight rise in both serum and abomasal immunoglobulin after administrating a challenge infection to sheep previously infected *H. contortus*. Moreover, the abomasal mucosal IgA rose rapidly after sheep were challenged. Inspite of the high IgA in the intestinal lumen, its role in protective immunity is still unclear.

In their study, Gomez-Munoz *et al.* (1999) investigated the relationship between primary or secondary serum responses and worm burden; and demonstrated partially induced protective response, characterized by higher serum protein levels, lower faecal egg counts, and reduction in establishment rate of abomasal parasite following primary infection in sheep (Smith *et al.*, 1993). The specific antibodies that were estimated using the enzyme-linked immunosorbent assay (ELISA) included the IgG, IgM and the IgA. (Lacroux *et al.,* 2006). The author explained that the interplay between the immune system and parasite led to different response to the infection.

2.6.6.8.4 Self cure

Periodic natural expulsion of adult *H. contortus* from sheep is known as "Self-cure" and in some cases this reaction appears to be immunological. It is suggested that the phenomenon is as a

result of an immediate-type hypersensitivity reaction provoked by antigens secreted by developing larvae. However, self-cure induced by a challenge infection is not always followed by protection since larvae in the challenge infection may develop to maturity (Luffau, *et. al.*, 1981).

2.6.6.9 Response of helminths to host immunity

Helminths are able to survive for long periods of time in their host and these multi-cellular parasites employ different strategies to render host defenses ineffective (Hoste, 2001). One of such mechanisms of evading the immune system is by development of migratory strategies away from mucosal immune defense mechanism. For example, *Ancyclostoma duodenale* has been reported to undergo hypobiosis in the muscle of its definitive host (Loukas and Prociv, 2001).

Following infection helminths activate the immune response through the complement pathway which leads to host inflammatory reaction. This cellular reaction could be sufficient to cause cytolysis of the juvenile stage of the parasite, but when these develop into the adult stage, these parasites are able to develop resistance against host immune system (Brake, 2003). For example, the schistosome worm disguises by acquiring the outer surface of the host which reduces its antigenicity or secretes proteases which cleave peptides anchoring the glycocalyx coat to the tegument of the worm thus allowing the shedding of the parasite coat (Haslam *et al.*, 1996). The most important mechanism, by which helminthes evade host immunity, is by secreting enzymes which acts to encourage the establishment and maintenance of helminthes within the host. Most parasitic helminthes are known to secret proteinases or proteolytic enzymes which facilitate the penetration of the host tissue by helminthes.

In Spain, Ruize *et al.* (1999) evaluated the antigenicity of the cystein proteases of *H. contortus* isolated from a goat strain against caprine haemonchosis and found that the egg per gram (epg) of faeces was significantly higher in unvaccinated goats than the vaccinated, indicating that the proteolytic enzymes are important in caprine haemonchosis amongst other enzymes. It is being anticipated that these helminths acquire nutrients as they invade the tissues, therefore competing with the host for nutrients.

Parasitic helminths are able to secrete enzymes, capable of scavenging the toxin produced by immune-effector cells of the host. For example, superoxide dismutase produced by the worm is used to neutralize host-reactive oxygen intermediates produced by the respiratory system of the host. Similarly, the glutathione S-transferase present in all parasitic helminths can detoxify exogenously produced toxic compounds including antihelminthic drugs as well as endogenously derived products of lipid peri-oxidation (Knox, 1994). The excretory and secretory products of both adult and larva stage of some parasitic helminths are shown to contain acetylcholinesterase, which is secreted by gastro-intestinal nematodes which may act to inhibit local gut peristalsis.

2.6.6.10 Diagnosis

Diagnosis is the procedure by which the presence of the parasite within the host is determined. Most samples may include faeces, for gastrointestinal helminths, *H. contortus* inclusive (Njau, 1987; Cabaret, *et. al*. 1998). Other samples that may be collected include urine (e.g Stephanuriasis and schistosomiasis), blood and skin scrapings.

To detect the presence of *H. contortus* in a host, faecal sample is taken from the rectum and the simple flotation technique is used to detect its eggs. The severity may be determined by the McMaster egg counting technique (Soulsby 1982). The use of faecal examination is not conclusive on the genera of the helminths and the egg identified may be described as strongyle eggs, indicating that the faeces is positive for any helminth belonging to either family strongylidae or trichostrongylidae (Fagbemi and Dipeolu, 1982; Kamal *et. al.,* 1993). The faecal examination involves identification of egg types in individual or composite samples. The composite sampling can be a valid alternative to individual examination, when samples are submitted from different flocks or herds of animal (Ward *et al.,* 1997). Gasbere *et al.* (1996) stated that there was no difference in the mean epg when they compare individual versus herd values.

To identify the genera, the faecal culture and examination of the infective larvae ($L_{3)}$ is needed. The faeces is incubated at 27^{o}C for 7 days in sterile faecal material (Waruiru *et al.,* 1994). The identification of the genera of the worm is done by examining the larval morphology (Mbaria *et al.,* 1995) to note the shape of the cranial extremities, number of intestinal cells, length of sheath tails, amongst others (Van Wyk *et al.,* 2004). The adult of *H. contortus* obtained from the abomasa could also serve as a diagnostic tool of type of helminth infection. Scott *et al.,* (1999) used the distribution of pepsinogen within the abomasa of sheep. Since *H. contortus* infection is associated with generalized hyperplasia and increase in number of the mucopeptic cells, these cells potentially increased the amount of pepsinogen in the abomasum.

At necropsy or slaughter, the presence of adult worms within the abomasa, is a confirmatory diagnosis for haemonchosis. Clinically the presence of antibodies specific to *H. contortus* serves both as a diagnostic tool or an immunological evidence of vaccination. The presence of *H. contortus* in the environment (Stromberg, 1997) can also be determined through examination of the pasture for infective larvae where animals are grazing (Fernandez *et al.,* 2001).

2.6.6.11 Control

The control of helminthosis particularly haemonchosis, will depend on the epidemiology of the parasites in the environment (Mitchell, 2005). The knowledge of the life cycle of the parasites is required to design strategies to reduce its impact (Githigia *et al.,* 2001) for greater economic returns (Gicheha *et al.,* 2005).

The most important factor to note in the life cycle of *H. contortus* is the ability of the larva to undergo arrested development, remaining in the abomasum during unfavorable condition without maturing to adult until after several months (Ogunsusi, 1979). Normally the worm requires about 3 weeks completing its life cycle but in arrested development, the life cycle is shorter leading to severe parasitism within 7-10 days when a large dose of larvae is ingested. (Luginbuhl, 1998).

2.6.6.11.1 Chemotherapy

i Types of dosing and conventional anthelmintic

The most important objective of the control programme should be to reduce economic losses and contain the parasite population to levels that do not significantly affect the productivity of the host, by the use of anthelmintics (Sangster, 1999). Prevention rather than cure is the phenomenon; therefore the following therapeutic management may be postulated.

Strategic deworming:

The antihelmintic is administered when the parasite population is concentrated in the host, transmission rate is low and therefore herbage contamination is at its annual low. In Nigeria, the recommended practice is to treat animals against helminthosis at the early, mid and late rainy season (Alawa, 2003). The strategic deworming of the animals in early and late rainy particularly when larvicidal anthelmintics are used will reduce the impact of arrested development of *H. contortus*. In their study, Bakunzi and Serumaga-Zake (2000) demonstrated that treating communally grazed sheep every 12 weeks, relatively reduced egg counts and was advantageous in providing seasonal control to helminths in semi – arid region of South Africa. The most effective deworming was every 4 weeks, although practically impossible in developing countries.

Tactical deworming

The tactical deworming is carried out by administering anthelmintic, when the weather is favourable for development of the parasites (Machen *et al.*, 2006). In Nigeria, this coincides with

the rainy season when moisture is high for development and larvae can move easily from faeces to pastures. The timing of the tactical treatment is usually based on recent precipitation, warm weather or increased faecal egg count.

Anthelmintics

Benzimidazoles

Members of this group of anthelmintics include the following thiabendazole, fenbendazole, belong to the oldest available drugs in the environment and are broad-spectrum. They act by binding to the tubulins of the nematode, therefore disrupting cell division but most importantly they act to inhibit furmarate reductase, causing mitochondria malfunction and death due to energy deprivation. There is evidence to show that goats metabolise this groups of drug differently from sheep, thereby requiring higher doses than sheep. Generally the dosage in sheep ranges between 5 to 10mg/kg. It is important that the doses of these drugs are adhered to, because when a worm becomes resistant to one member of the group, it is resistant to all members of the group. Resistance to the benzimidazoles by *H contortus* has been reported world-wide (Waller *et al.,* 1996; Requejo-fernandez, *et al.,* 1997; Waruiru, Ngotho and Mukiri, 1998; Smith *et al.,* 1999; Hoque, *et.al.,* 2003; Torres – Acosta *et al;* 2003).

In recent times resistance to this group of antihelmintics has necessitated the use of other classes of dewormer and or strategic management practice.

Macrolides (macrocyclic lactones)

These broad spectrum anthelmintics are also effective against arthropods. These drugs include the ivermectin, dormectin, eprinomectin and recently, moxidectin (Cringoli *et al.,* 2003) which

were originally derived from the microorganism S*teptomyces cyaneogriseus.* The mode of action of this group of compounds is by hyperpolarization of the parasitic neurons leading to paralysis and death of the parasite (Costa *et al.,* 1998). The efficacy of this group of anthelmintic is significant even at very low doses. In evaluating the role of ivermectin, Rahman (1997) demonstrated that when given at 0.2 mg/kg body weight, there was decreased faecal egg count and total worm burden of *H. contortus*. Likewise, Waruiru (1997) reported a 100% efficacy when he compared ivermectin at 0.2mg/kg body weight against other antihelmintics in sheep. Ivermectin is available as an injectable for cattle and drench of sheep. Experimentally, the oral form is more effective in goats, requiring a shorter withdrawal period.

Levamisoles

Levamisole is a cholinergic antihelmintic, acting as an agonist at the nicotinic acetycholine receptor. Levamisole, like other nicotinic anthelmintic (morantel, pyrantel), acts at the neuromuscular junction to cause spastic paralysis of the nematode. In the midst of resistance against benzimidazole group of antihelminthc, levamisole has been found to be a cheap and farmer-convenient alternative to the ivermectin group. In a controlled trial, Ibarra – Velarde *et al*. (2001) treated different groups of cattle with the following anthelmintic: netobin, 20mg/kg; triclabendazole, 12mg/kg; levamisole, 5.5mg/kg and ivermectin, 200ug/kg and following euthanasia of the cows eight days post treatment, levamisole reduced gastrointestinal nematodes by 95.8%. Even with this classes of drugs, resistance has been reported although not as wide spread as with the bendamidazole group.

ii Anthelmintic resistance

Resistance is said to occur when a greater frequency of individual in a parasite population usually affected by a dose or concentration of a compound are no longer affected by the drug or a greater concentration of the drug is required to reach a certain level of efficacy (Wolstenholme *et al.,* 2004). Sources of resistance include the administration of insufficient dose, inappropriate route of administration using ineffective compound or massive re-exposure to the helminth.

Anthelmintic – resistant nematodes are becoming a major problem in livestock, particularly small ruminants Resistance has been reported in all the major classes of broad spectrum antihelmintic (Sissay *et al*., 2006). Although the mechanism of resistance may be varied, generally resistance is acquired either by loss of receptor or decrease of the largest site affinity for the drug (Kohler, 2001).

It has been postulated that resistance could arise from the following ways.

- Change in molecular target, so that the drug does not recognize its target
- Change in metabolism, thereby inactivating or removing the drug.
- Change in distribution of the drug in the target, hence preventing the drug from accessing its site.
- Amplification of target genes to overcome the drug (Wolstenholme *et. al.*, 2004).

Waruiru *et al.* (1998) reported a simultaneous resistance of *H. contortus* against benzimidazoles, levamisole, and ivermectin in a controlled trial in Kenya. Torres Acosta *et al.* (2003) and

Chartier *et al.* (1998) also indicated that *H. contortus* was the only resistant genus demonstrated in a post-treatment larva culture. Resistance to one member of a group of helminths means resistance to all members of group, and *Haemonchus contortus* has been reported to be resistant to all the classes of antihelmintics. Therefore as a parasite that is wide spread, blood-feeding and now resistant, it requires other non-conventional method of control.

iii Anthelmintic plants

Since the development of resistance in helminths against commonly available anthelmintics, there has been growing challenge in exploiting the anthelmintic potential of some plants (Hordegen *et al.* 2003). Smallholder farmers in developing countries are unable to afford synthetic anthelmintics, therefore necessitating the need for affordable and accessible alternatives (Akhtar *et al.* 2000). Ethno-veterinary medicine is now being developed to identify and document traditional methods of managing and treating livestock diseases (Ibrahim *et al.* 1983). A wide range of plants are in the process of identification as anthelmintics. For example, Alawa (2003) investigated the anthelmintic properties of *Vernonia anygdalma* and *Annona senegalensis*, although *Vernonia anygdalma* did not show any significant anthelmintic activity, *Annona senegalensis* caused significant reduction in egg hatch at concentration of 7.1mg/ml *in vitro*; and a lower larval recovery with increasing concentration. Condensed tannins which are polyphenolic compound found in leaves and stems of many forage species (Athanasiadou *et al.* 2001, Min *et al.*, 2004), may have direct or indirect anti-parasitic effects. Tannins are important in animal nutrition, where they may cause adverse or beneficial effects on nutrient utilization consequently affecting health and production (Nguyen *et al.* 2005). The possible mode of action of condense tannins as anthelmintic, is through mediation of the tannin-nematode interaction, thereby reducing nematode viability (Paolini *et al.*, 2003). Recent studies have reported that the

guava leaves *Mimisa spp* and *Femingia mucrosphylla* have effect on larva of *H. contortus* in vitro. Hordegen *et al.* (2003) in comparing 5 plants, deduced that the ethanol extract of *Fumaria parviflora* was as effective as pyrantel tartrate.

2.6.6.11.2 Biological control

The need for affordable and accessible treatments for parasites has led to identification of biological method of controlling these parasites. This method of control involves feeding of other microorganisms which will in turn kill the parasite. *Duddingtonia flagranis* is a fungus which has been used to kill nematode, thereby controlling their devastating effect (Larsen *et al.* 1997; Waller et *al.,* 2001). Fontenot *et al.* (2003) and Iwoghorn *et al.* (2003) demonstrated larva reduction of between 40-93% depending on the dose of fungus given. Chandrawatahni *et al.* (2003) and Wright *et al.* (2003) fed *D flagrans* at dose rate of 125,000 and 250,000 spores per kilogram body weight, and found that the higher dose had higher (>99%) larvae reduction than the lower dose. Fontenot *et al.* (2003) fed *D flagrans* as supplements in feed blocks, and reported that *D flagrans* is able to survive the manufacturing process and resulted in significant reductions in larvae numbers indicating that supplementary feeding or block administration offer potential feeding strategies for biological control of nematode parasitic to livestock.

2.6.6.11.3 Vaccination

i Vaccines against *Haemonchus contortus*

Following failures of anthelmintic and pasture control of helminths, scientists have focused attention in the development of vaccines that will reduce worm infection in livestock species. In the 1960s and early 1970, vaccination of calves with attenuated irradiated *Dictyocaulus viviparus* larvae (Meeusen *et al.,* 2007) stimulated a high degree of protection against natural challenge.

With some success, the work was also intensified using attenuated irradiated *H. contortus* and *T. colubriformis* with protection only in sexually matured sheep and very limited and weak response in growing lambs. Although not fully understood, it is known that immune mechanism against helminths is complex involving local hypersensitivity, cell-mediated, humoral and inflammatory responses. This is further compounded by the fact that lambs and peri-parturient ewes are thought to be naturally non-responsive to these immune processes, this may be so because it has been suggested that lambs may have circulatory maternal antibodies, while immuno-suppression may be responsible for the weak immunity in peri-parturient ewes.

The initial attempts in antigen isolation involved using whole ground-up helminth mixture to variable purified antigens for immunization against parasite of livestock animals, during which research was directed at the use of antigens that can be recognized by the body without being detected by the helminth. This is because the *H. contortus* feeds on blood, therefore it is possible to deliver antigen that will elicit immune response directed against the gut surfaces of the parasite and coupled with the fact that, sheep grazing pasture are able to gradually acquire immunity (Hein and Harrison, 2005). It therefore means that protection with successful vaccines can achieve immunity until when the lamb might have acquired immunity from grazing, which is usually about 6 months of age.

For a vaccine to be effective, it must have the following characteristics

- It should reduce ability of Larva stage L_3 to penetrate host tissue.
- It should be able to attenuate the development of L_3 into fully matured blood feeding adult.
- It should also reduce blood feeding adults.

- It should be able to reduce the fecundity of the adult helminthes (Vercruysse *et al.* 2004).

ii Helminth proteins as antigens

Proteins were the first choice of chemical to be analyzed since they are relatively easy to identify, modify and be produced in economically large quantities, and play a significant role in parasitic metabolism.

Haemonchus contortus was reported to release a variety of excretory and secretory products (ESP) into the host which are proteinous in nature and, were found to induce about 90% protection in sheep, leading to the quest for structurally isolating, characterizing and fractionalizing them (Schallig *et al.,* 1997). Using different proteomic tools Yatsuda *et al.* (2003) analyzed the ESP and reported that they contained 107 proteins located in 102 spots, but of importance in this was the identification of the H11. The H11 is a glycoprotein which is novel and was yet to be found in the ESP of this helminth.

Novel or hidden antigens are antigens that are located in the inner lumen of the intestines of helminths, so that when sheep is immunized with theses gut membrane antigen, they produce high circulatory antibodies. Evidently when the helminth feeds on the host, it ingests the antibody which binds to the brush border of the parasitic intestines, disrupting digestion, leading to starvation, loss of fecundity and weakness (Newton *et al.,* 1995; Newton and Munn 1999) after which the parasite is detached from the host gastrointestinal tract. An added advantage is that being hidden the host does not respond to this antigen during natural infection. Consequently the parasite had not needed to counteract the host response.

Newton (1995), Schallig *et al.* (1997a) and Jasmer *et al.* (2007) demonstrated that the ESP antigens of *H. contortus* that reacted with sera of infected sheep ranged from 11 to 300KDa and response included proliferation of Polymononuclear cells, loss of motility of helminth, inhibition of host monocytes and reduction in mean egg count. In particular Jasmer *et al.* (2007) were able to confirm that the intestine of adult *H. contortus* contained antigen that could stimulate local abomasal CD4+ and CD25+ T lymphocytes response.

A lot of progress has been made in isolating and characterizing protective antigens but reproducing these properties into recombinant vaccine has been slow. These may be attributed to the following

- Poor selection of biologically relevant targets
- Inappropriate expression of the recombinant proteins
- Lack of knowledge about how (adjuvant) the vaccines need to be delivered to the animals in order to induce protective immunity.

The difficulties encountered when expressing the protein antigen in bacteria or yeast may be due to the incorrect folding of the proteins or lack of glycosylation of the expressed protein. Therefore efforts are now being focused on the use of helminth glycan as potential vaccine antigens.

iii Helminth glycan as antigens

Carbohydrates as antigens of animal parasitic nematodes have structurally been characterized to contain O and N- glycoproteins, glycolipids and other glycans. . The glycans of cestode although yet to be fully investigated had provided the matrix for future research in other parasitic animals.

Echinococcus multilocularis and *D. viviparus* were characterized and reported to possess N-linked glycan and that of *D. viviparus* was said to be similar to that found in human leucocytes. In trying to identify the different glycan antigens, Haslam *et al.* (1996), studied the homogenized adult *H. contortus* and demonstrated H11 as an immunogically significant glycoprotein. Similarly when Smith *et al*. (1994) isolated and fractionalized the glycoproteins in the lumen, they discovered they contain antigens that in immunized sheep there was selective binding to lectin which was specific to N-acetlygalactosamine. And immune response was expressed as reduction in mean worm burden and egg count at the rate of 72 and 90% respectively (Knox *et al.* 1999). The most promising glycan antigen is the galactose-containing glycoprotein complex isolated from the intestinal membranes of *H. contortus* termed H-gal-GP complex (Geldhof *et al.* 2005; Smith *et al.* 2003ab). The complex is localized to the brush-border of the intestinal lumen of the parasite and in vaccinated sheep; it's bound by specific antibodies ingested with the blood meal, thereby resulting in reduction in worm egg count and lowered worm burden (Smith *et al.,* 2007). The success generated so far may be linked to the fact that the antibodies produced in the intestine mucus are predominantly directed against the carbohydrate larval antigen found only on the surface of the infective larva and not present on other stages of the nematodes. These antibodies directed against the infective larvae could be used to truncate the life cycle of the parasite preventing it from reaching maturity.

2.6.6.11.4 Pasture management

The desire to successfully sustain parasite control requires knowledge of the dynamics of egg shedding from the host, seasonal larval availability and information about climatic requirements for egg hatching and larva development and survival at pastures. In outbreaks of parasitic

gastroenteritis, prompt administration of appropriate therapy must be carried out to minimize death or production losses. Sub-clinical infections, also pose production losses. Therefore to avoid these problems, nematode control should combine treatment and management (Borgstede *et al.,* 1998). These strategies are aimed at preventing accumulation of parasitic larvae on pasture or reducing the acquisition of infection by anticipating the period during which large numbers of larvae are likely to contaminate pasture. It is clear therefore that parasitic larvae cannot be eradicated but minimized to a manageable level.

This involves alternating grazing of species which do not acquire each other's parasites (Githigia *et al.,* 2001). Animals that will be rotated should be treated with an antihelmintic within a few days of entering the pasture to prevent introduction of parasites onto the pasture. If animals will remain on the pasture for extended period of time, they should be treated with a second dose of antihelmintic to ensure that contamination is at its minimum. The management of pastures along with treatment at time of peak egg shedding allows the larvae to die off during periods when the pastures are not grazed. Similarly moving livestock to crop residue, after harvesting non-grazed crop has been shown to provide relatively safe pasture.

3 MATERIALS AND METHODS

3.1 Study site

The study was conducted at the National Animal Production Research Institute, (NAPRI), Shika, Ahmadu Bello University, Zaria, Nigeria. Shika is situated in the Northern Guinea Savannah between latitudes 11^{o} and 12^{0} N, and between longitudes 7^{o} and 8^{0} E; at an altitude of 650m; with a mean annual rainfall of 1150mm. The climate of the site is sub humid; rainfall is well distributed during the rainy season, with about 70% of the rain occurring during the months of July and August. The average temperature and humidity during the wet season are 24.7^{o} C and 72% respectively. The early dry season commences from October with a period of cold dry weather known as harmattan lasting until February. This is followed by the hot weather when temperatures fluctuate during day (14-34^{o}C) with a relative humidity of between 10-20% (Amodu *et al.*, 2001).

3.2 *Experiment I*

3.2.1 Experimental animals and design

Ten does, 5 Sahelian and 5 Red Sokoto, aged between 2 and 3 years with average live weight of 21.02 $\pm$ 0.54kg were used for the study in a completely randomized design where breed was the treatment. Goats were selected from the Small Ruminant Research Programme (SRRP) flock where they are annually vaccinated against petit de pestes ruminae (PPR) virus and routinely treated against both endo and ecto-parasites using ivomectin at 200ug/kg body weight. These does were synchronized with progesterone sponges and hand-mated, so as to achieve uniform kidding and proper management of kids. Does were individually housed two weeks prior to their expected date of kidding. Following parturition, kids and dams were housed in the same pen till the end of the experiment, which lasted 12 weeks.

Null hypothesis: There was no difference in the milk production characteristics between the Red Sokoto and Sahelian breeds of goats.

3.2.2 Feeds and Feeding.

The concentrate was fed to the animals at 0800hrs and the animals were allowed to consume all, after which maize stover and water were provided *ad libitum.* Animals were fed maize stover at the rate of 1kg per head, and concentrate at 4% of the combined dam and kid weight. The composition of the concentrate consisted of the following ingredients: maize (26.1%); wheat offal (27.8%); cottonseed cake (43.1%); bone meal (2%); and salt (1%). The diet was compounded to meet the 16% recommended crude protein requirement for maintenance and production in goats. Kids were allowed to suckle their dams for a week before experiment commenced. Prior to the study dams grazed the range land.

3.2.3 Sample collection and analysis

Representative samples of the maize stover, concentrate and milk were collected weekly and analysed for dry matter (DM), nitrogen (N), and ash while milk samples were analysed for total solids and fat according to AOAC (1990) procedures.. Weekly live weights of both does and kids were recorded. Milk production was estimated by twice-weekly hand-milking of does. On the night preceding the milking, kids were separated from their dams for 12hrs. The next morning does were completely hand-milked and quantity of milk recorded (Ehoche and Buvanendran.1983). The recorded milk was multiplied by 2 since it was a collection over a period of 12hrs to obtain the daily milk yield (Bencini, *et. al.,* 2003).

3.3 Experiment II

3.3.1 Experimental animals and design

At weaning, (3-months) a total of 27 kids, comprising 18 Sahelian (10 males, 8 females) and 9 Red Sokoto (5 males, 4 females) kids, were involved in a growth trial that lasted 150days. The kids were weaned from the dams in experiment 1 as well as other dams in the flock. Each group was made up of 5 males and 4 females and fed according to sex. The 2 groups of Sahelian were made of the 2 different colours. Mineral licks (Whitebarn Limited, Winsford, U. K.), and water were provided *ad libitum*.

Null hypothesis: There is no difference between the Red Sokoto and Sahelian kids in terms of their growth performance.

3.3.2 Feeds and feeding

A total of 9 pens were used for the experiment. Kids in each group were blocked according to weight and then group-fed with a maximum of three animals per pen. Thus kids that were almost of the same weight were fed together to avoid vicious competition. Concentrate was offered at 0800h, hay was offered after the concentrate had been consumed. Animals were weighed at the beginning of the experiment and thereafter weekly. The weekly live weights were used to adjust the quantity of feed to be offered to ensure that the goats were fed adequately to support maintenance and growth of the kids. Water was provided *ad libitum*

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3.3.3 Digestibility trials.

At the end of the growth trial, animals were transferred to individual metabolic crates for 10 days to determine digestibility of the feed. Animals were moved to metabolism crates and allowed to

adjust to the crates for 3days (Tripathi *et. al.*, 2001). Data on feed offered, feed refused and feed intake were recorded for 7 consecutive days. Faeces was collected from individual animal and weighed daily. About 100g was immediately dried at 105 for 24 hrs for DM determination, after which, 10% was sub- sampled and bulked for chemical analysis. Kids were fed as in 3.3.2.

3.3.4 Data collection and statistical analysis

The feed intake, average daily gain, and digestibility coefficient data were analysed using the general linear model (GLM) procedures in the Statistical Analysis System (SAS, 2000). Mixed procedures (SAS 2000) were used for the repeated measures analysis of the milk yield data. The difference between treatments means were tested using pair-wise difference, PDIFF. All differences were considered significant at $P<0.05$.

3.4 Experiment III

3.4.1 Experimental animals and design

Thirty kids that were weaned after 3months and used for the growth trial were used for this study. Some kids were taken from the main flock and added to the trial. The experimental animals comprised 15 kids each of Sahelian and Red Sokoto breeds each. Kids were divided into three groups, each group having 5 kids of each breed. Thereafter, each group was allocated to one of the treatments. Animals were then housed in group based on their treatment levels and breed. The kids were fed concentrate diet as in experiment 1 and transferred to their group feeding pens. Ten animals were used per treatment, i.e 5 per breed. Kids were fed concentrate at 0800h and given *Digitaria* hay *ad libitum*.

Blood and faecal samples were taken to ascertain their parasitic status before commencing the experiment. The animals had coccidia oocysts in their faeces and were treated using Sulphadimidine parenteral preparation for 5days. Ten kids in treatment 1 were the controls, and did not receive any infection; those in treatment 2 (10 kids) were given 75 larvae (L3) per kg live weight given as trickle infection 3times per week for 3 weeks. While kids (10 kids) in treatment 3 had 100 L3 /kg live weight 3 times a week for 3week. (Romjali *et al.,* 1996 and Wallace *et al.,* 1996). Weight changes were recorded weekly. They were slaughtered at the end of 10 weeks; worm load and carcass composition were determined.

Null hypothesis: Growing Red Sokoto and Sahelian growing kids show similar response to H. contortus infection with respect to their weight changes, Packed Cell Volume, faecal egg count, serum proteins and abomasal helminth counts.

3.4.2 Laboratory Examination:

3.4.2.1 Parasite collection and faecal culture

Adult Haemonchus contortus were collected from four small ruminant slaughter slabs around Zaria. These were obtained during the different market days of Makarfi, Tudun Saibu, Dogarawa and Giwa local markets. Visits to the slaughter slabs were made early in the morning so as to purchase as many abomasums as possible. The abomasums were put in a nylon bag and transported to the Helminthology Laboratory of the Department of Veterinary Parasitology and Entomology. In the laboratory, they were thoroughly washed to harvest all the adult helminths within the abomasum, after which the parasites were crushed to release the eggs for subsequent incubation in sterile faecal material at 37^{o} C for 7 days. A volume of the larvae solution was

made and a known quantity was taken for counting to estimate the concentration of the larvae per milliliter of the solution.

3.4.2.2 Parasitological techniques

Weekly faecal samples were collected directly from the rectum of animals. About 2g of faeces was transferred to a tube, 5-6 glass beads were added and the container filled with water. The content was then thoroughly mixed to obtain a suspension. The suspension was then washed through a 150µm sieve and then through a 38 µm sieve. The material left in the sieve was back-washed and transferred into a centrifuge tube. The tube was centrifuged at 1500-2000r.p.m for 2 minutes and the supernatant discarded. Five militre of Magnesium sulphate (1.2spg) was added, and the tube again centrifuged for 2 minutes; after which the supernatant was poured into a clean polythene tube and kept aside, while same volume $MgS0_4$ was again added to the tube and centrifuged. The supernatant was also collected into the tube containing the first centrifugation, to which $MgS0_4$ was added to the 12ml line. The content of the tube was poured into a 30ml polythene bottle with dropper, the bottle was shaken and a few drops were discarded from the dropper. The modified McMaster counting chambers were filled and allowed to stand for 10minutes before counting under x10 objective lens. The egg per gram was calculated thus: side 1 + side 2 counts x 20 (Sloss *et al*. 1994, Bowman. 1999).

3.4.2.3. Blood collection and analysis

About 10mls of blood was collected weekly from the jugular vein into 2 tubes, one tube containing Ethylene Diamine Tetracetic Acid (EDTA) as anticoagulant for haematological determination and the second tube without EDTA, for serological analysis. The serum was preserved at 0^0C until when required for serology.

3.4.2.3.1 Packed Cell Volume

A plain capillary tube (75 X 1.0mm) was filled to approximately 1cm from the tip with blood containing anticoagulant. One end of the tube was sealed by holding it over flame. The tubes were placed in the microhaematocrit centrifuge and centrifuged at 10,000rpm for five minutes. The tubes were placed on the scale with the meniscus of the plasma on the top line of the haematocrit tube reader for accurate estimation of the PCV (Benjamin, 1978).

3.4.2.3.2 Total protein

The principles behind the Buiret method for determination of serum total proteins is the production of colour change following the reaction of copper in alkaline solution and peptide bonds. The intensity of the colour change is proportional to the amount of protein present in the serum. A standard solution (0.1mls) which contains bovine serum and saline at ratio 1:5 was added to buiret solution (5.9mls) in a tube. 0.1mls of the test serum was also added to 5.9ml of buiret solution, in another tube and both tubes incubated at 37^0C for 10minutes. Prior to reading the value for the total protein, water was used to calibrate the instrument and values were read at 540nm. The value was calculated thus: Test-Blank/std-Blank x concentration (60g/L) (Coles, 1974).

3.4.2.3.3 Serum albumin.

The value of serum globulin is usually obtained by calculating the difference between total protein and albumin. The principle in serum albumin determination involves its reaction with the bromocresol green (BCG). Dye-albumin has affinity for BCG dye in acidic solution, producing a colour complex which is measured with a colorimeter. Similarly, the intensity of colour produced is proportional to the concentration of albumin in the serum sample. The standard solution consists of bovine serum albumin and normal saline at ratio 1:10. The serum sample (0.02mls) is mixed with washing colour solution (0.4mls) and incubated at 37^0C for 10minutes. Unlike the total protein where water was used to calibate the instrument, for the albumin, BCG was used to standardize the instrument.

Albumin level was calculated thus: - Optical density of test serum/Optical density of standard X concentration of standard.

Therefore globulin level = Total protein-albumin (Coles, 1974).

3.4 Experiment IV

3.4.1 Experimental animals and design

Five lactating *does* from the Red Sokoto breed were infected with *H. contortus* larvae at two levels; low ($75L_3$/kg liveweight) and high (100 $75L_3$/kg liveweight) while five served as uninfected control. Due to shortage of lactating Sahelian *does*, 5 *does* were infected at low level while five *does* served as control. Animals were housed a week after parturition and infected as in experiment 3. The kids were allowed to suckle the dam to obtain colostrums for one week

prior to infection with *H. contortus* larvae and thereafter allowed to run with their dam. Feed and water were provided as in experiment 2, but *Digitaria simutsii* was the roughage. Does and Kids were weighed weekly. Experiment lasted 12 weeks. The experimental design is a 3x2 factorial design.

Null hypothesis: There is no difference in the weight changes, milk production, faecal egg count, packed cell volume and serum proteins of lactating Red Sokoto and Sahelian does infected with H. contortus .

3.4.2 Laboratory analysis

Parasitology examination of faeces was as in experiment 3 while milk yield and chemical composition were determined as in experiment 2. Blood samples were taken and analysed as described in experiment 3.

3.4.3 Statistical analysis of data

Analysis was made of the weight changes, intake and digestibility. The difference in faecal egg count between the breeds was analyzed by repeated measures of variance using the general linear model procedure of SAS (2000) package.

4. RESULTS

4. 1 Experiment I

4.1.1 Chemical composition of feed

The chemical composition of supplement and hay are presented in Table 1 the protein content of the hay was 7.7%, while that of the supplement was 20.6%.

Table 2: Feed ingredients and their chemical composition

Diet	Dry matter (%)	Organic matter (%)	Crude protein (%)	Ash
Supplement	95.6	90.2	20.6	5.4
Hay	93.6	85.9	7.7	7.7
Maize stover	91.7	89.6	4.1	2.1

4.1.1 Weight change

The least square mean live weight of the Sahelian *does* was 20.9±2.21kg which was not significantly (P>0.05) different from that for the Red Sokoto *does*. (20.8±1.97kg). Two weeks into lactation period, both breeds of goats showed a decrease of 8.3% in live weight, reaching maximum weight loss by 9th week, with a total decrease of 17.4% of their liveweight (Table 3).

Thereafter, there was a slight weight gain but this gain did not attain the prenatal liveweight. The birth weight of the kids was significantly higher (P<005) in the Sahelian kids than the Red Sokoto kids (Table 3). The Kids showed an exponential increase in weight from birth until they were weaned at 3months. However, the Sahelian kids had a decrease in weight gain by 11th week, while the Red Sokoto had a decrease in weight gain in the 8th week. The mean birth and weaning weight for the male Red Sokoto kids were 1.5±0.23 and 8.4±0.64kg while that for the male Sahelian were 2.5±0.23 and 7.7±0.64kg respectively. The weaning weights of the males were significantly higher than that of the female irrespective of the breed. The weaning weight for the female Red Sokoto kids 1.0±0.23 and 7.5±0.64kg and the Sahelian at 1.6±0.23 and 6.9±0.64kg respectively. (Table 4) The male kids showed a consistent liveweight gain through-out the duration of the study.

Table 3: Least square means (M±SE) of liveweight and milk yield of Red Sokoto and Sahelian goats.

Parameter	Red Sokoto	Sahelian	Average	SE
Mean Dam Weight (kg)	20.8[a]	20.9[a]	20.8	0.54
Birth Weight (kg)	1.0[b]	2.2[a]	1.6	0.23
Weaning Weight (kg)	3.9 [b]	5.6 [a]	4.7	0.43
Kid weight (kg)	3.4 [b]	4.3 [a]	3.9	0.12
Female kid (kg)	2.8 [b]	4.2 [a]	3.4	0.12
Male kid (kg)	3.8 [b]	4.4 [a]	4.1	0.19
Milk yield (ml)	135.9a	134.7a	135.3	17.49
Total solids(%)	16.4 [a]	15.1 [b]	15.7	0.40
Milk fat (%)	3.7 [a]	3.2 [b]	3.5	0.13
Total milk yield (lt)	24.5[a]	23.3[a]	23.9	0.67

[ab] Means (M±SE) in the same row bearing different superscript letter differ significantly ($P<0.05$)

4.1.2 Milk yield and Composition

The results of milk yield and chemical composition are presented in Table 3. The average daily milk production was 134.7±17.52 and 135.9±17.46ml for the Sahelian and Red Sokoto breeds of goats respectively. Although through out the lactation period the Sahelian goats produced slightly less milk than the Red Sokoto, there was no significant difference ($P>0.05$) between the 2 breeds at any time during the observation. The duration of lactation influenced the milk yield. The Red Sokoto does had the highest milk yield in week 1, after which there was a gradual decrease, while the Sahelian had the highest yield at week 6. Red Sokoto goats had significantly ($P<0.05$) higher milk total solids (16.38%) and milk fat (3.7%) than the Sahelian with corresponding values of 15.06% and 3.2%. .

4.2 Experiment II

The results of the birth, weaning weights and average daily gain are presented in Table 4. Overall, the female kids had significantly ($P<0.05$) lower birth weight and weaning weights than the male kids. The Sahelian kids had significantly ($P<0.05$) higher birth weights (2.2kg) than the Red Sokoto kids (1.0kg). The males significantly ($P<0.05$) had higher birth weight, weaning and average daily gain than the females. For average daily gain and total weight change, there were breed and sex effects. The Red Sokoto had significantly ($P<0.05$) higher average daily gain and weight change of 66.9±1.59 g/day and 6.3±0.64 out performing the Sahelian with average daily gain of 46.7±1.59g/day and 5.3±0.64kg total weight change. The mean of intake and digestibility parameters are presented in Table 5.

Table 4: Least square means (M±SE) of birth weight, weaning weight and weight change of Red Sokoto and Sahelian breeds of goats.

	Red Sokoto	Sahelian	Red Sokoto Female	Red Sokoto Male	Sahelian Female	Sahelian Male	SEM
Birth Weight (kg)	1.0[b]	2.2[a]	1.0[b]	1.5[a b]	1.6[a b]	2.5[a]	0.21
Weaning Weight (kg)	7.5[b]	7.8[a]	7.5[b]	8.4[a]	6.9[b]	7.7[a]	0.67
Initial Weight (kg)	14.8[a]	12.9[b]	13.6[b]	15.8[a]	11.9[b]	13.4[b]	1.16
Final Weight (kg)	18.9[a]	14.4[C]	16.7[b]	19.6[a]	12.6[C]	16.3	1.79
Weight Change (kg)	6.3[a]	5.6[b]	6.2[a]	6.4[a]	4.9[C]	6.3[a]	0.79
Average Daily Gain(g/day).	66.9[a]	46.6[b]	44.9[b]	61.9[a]	40.4[b]	46.7[b]	1.42

[ab] Means (M±SE) in the same row bearing different superscript letter differ significantly ($P<0.05$)

Table 5: Least square means of Intakes (g), digestibility (g/kg) of dry matter, organic matter and crude protein of Red Sokoto and Sahelian goats.

	Red Sokoto	Sahelian	Red Sokoto Female	Red Sokoto Male	Sahelian Female	Sahelian Male	SE
Dry Matter Intake (g/kg)	657.4	818.8	554.8	725.8	778.8	882.2	82.93
Organic matter intake (g/kg)	613.3	763.2	517.2	677.4	724.8	823.5	77.18
Nitrogen intake (g/kg)	99.6	120.4	81.4	111.7	107.1	139.2	12.23
Dry matter digestibility (%)	78.1	75.6	77.6	78.1	73.2	77.8	16.67
Organic matter digestibility (%)	78.6	76.4	78.0	78.6	73.9	78.6	14.61
Crude Protein digestibility (%)	63.2	55.2	62.3	64.9	52.6	57.7	13.87

4.3 Experiment III

4.3.1 Weight change.

The means for the weight changes are presented in Table 6. The Sahelian had higher liveweight (12.8±0.83 kg) than the Red Sokoto goats (9.7±0.83 kg). Also, the mean weight for the different treatment groups varied significantly based on the level of infection, ($P<0.05$). When the mean weight of the kids was analysed for the whole duration of the experiment, the control goats had the highest mean weight of 12.1±0.98kg while goats in the low and high levels of infection had mean values of 11.3±0.98 and 10.6± 1.10kg respectively. There was no difference between the mean final and initial weights in all the animals. For the control group, the difference between the initial and final weight was 0.7kg, while for the low and high infection groups, the Red Sokoto kids, 0.1 and -0.3kg respectively (Table 6). The corresponding values for the Sahelian goats were 0.8kg and -1.4kg respectively (Table 6). The difference between the weight at the end of experiment and the preinfection was 0.6kg and -0.6kg for the Red Sokoto and Sahelian breeds respectively (Table 6).

However the average daily gain was higher in the Red Sokoto (11.2g/day) than the Sahelian (5.7g/day) though the difference was not significant ($P>0.05$). Similarly, the average daily gain was not influenced by treatment but control goats had significantly higher ($P<0.05$) gain of 15.3g/day as compared to low and high infection group with 5.6 and 4.4g/day respectively.

Table 6: Weight changes (kg) in Red Sokoto and Sahelian goats experimentally infected with different levels of *H. contortus.*

	Red Sokoto						Sahelian					
	$0L_3$/kg	Diff	$75L_3$/kg	Dif	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff
0	10.5		9.5		9.1		13.8		13.7		12.7	
1	10.2	-0.2	9.3	-0.2	9.0	-0.1	13.9	0.1	13.4	-0.3	12.3	-0.4
2	10.0	-0.5	9.3	-0.2	8.8	-0.3	13.5	-0.3	13.1	-0.6	12.3	-0.4
3	10.3	-0.3	9.5	0	9.2	1	13.7	-0.3	13.1	-0.6	12.0	-0.7
4	10.0	-0.5	9.5	0	9.3	1	13.2	-0.6	13.0	-0.7	11.3	-1.4
5	10.4	-0.2	9.6	1	9.0	-0.1	13.4	-0.4	12.8	-0.9	11.8	-0.9
6	10.7	0.2	9.5	1	9.5	0.4	13.8	0	12.8	-0.9	11.9	-0.8
7	10.9	0.4	9.5	0	9.5	0.4	13.9	0.1	13.1	-0.3	11.8	-0.9
8	10.8	0.3	9.4	-0.1	9.5	0.4	14.0	0.2	12.9	-0.8	11.7	-1
9	11.2	0.7	9.5	0	9.7	0.3	14.3	0.5	12.6	-1.1	11.3	-1.4
10	11.3	0.8	9.4	-0.1	9.9	0.8	14.3	0.5	12.9	-0.8	11.3	-1.4
Mean	10.63^{bc}		9.5^{c}		9.3^{c}		13.8^{a}		13.1^{a}		11.8^{b}	
SE	1.41		1.41		1.57		1.41		1.41		1.57	
ADG	18.2		12.1		11.3		17.2		-1.8		-7.3	

4.3.2 Faecal egg counts.

The mean faecal egg count is shown in Table 7. Control goats were mostly negative throughout the experiment. The mean faecal egg count was significantly affected by breed and treatment. The Sahelian had significantly ($P<0.05$) higher (2143.3±153.4) mean epg than the Red Sokoto goats (579.3±147.5), by week 3 post infection. The peak faecal egg count was recorded at the 8^{th} and 11^{th} week post-infection for the Sahelian and Red Sokoto kids respectively. Treatment also significantly ($P<0.05$) influenced the mean epg, the control goats had mean epg of 16.0±186.07, while treatments 2 and 3 had mean epg of 1383±184.99 and 1726±182.04 respectively (Tables 7 and 8).

Similarly, period post-infection significantly ($P<0.05$) affected the mean egg output which steadily rose from 3.5±545.8 at week one post infection (PI) to reach the first peak of 1308±542.8 and a second peak of 1482.7±542.9 at week 8 PI in the Red Sokoto. The Sahelian had the first peak of 3467±563.5 in week 5 and a second peak of 2099±574.8 in week 9. Subsequently there was a decline up to week 10 .

Table 7: Least squares mean of untransformed epg of growing Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto			Sahelian		
	0	$75L_3$	$100L_3$	0	$75L_3$	$100L_3$
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	100	208
3	0	0	0	0	641	660
4	0	0	224	0	1500	3978
5	0	272	882	0	3352	6692
6	0	916	1256	0	2292	7960
7	0	2668	2831	0	1780	5368
8	0	936	2880	0	1804	3460
9	0	542	1055	0	3512	4296
10	0	448	2752	0	2090	2373
Mean	4.0	579	1245	3.0	1509	2817
SEM	1075.35	961.85	961.82	961.83	961.83	961.83

Table 8: Least squares mean of log_{10} epg of growing Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto			Sahelian		
	0	$75L_3$	$100L_3$	0	$75L_3$	$100L_3$
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	2.3	1.4
4	0	1.7	1.1	0	2.5	2.7
5	0	2.2	2.8	0	2.7	3.4
6	0	3.0	3.1	0	3.1	3.6
7	0	2.7	3.2	0	3.2	3.4
8	0	2.7	3.3	0	2.5	3.3
9	0	2.6	3.3	0.3	0.6	3.3
10	0	2.5	3.1	0	0.6	3.1
Mean	0.1	1.4	1.6	0.1	1.7	2.0
SEM	1.05	0.95	0.95	0.95	0.95	0.95

4.3.3 Packed Cell Volume

Table 9 shows the mean PCV, which did not significantly differ ($P>0.05$) between breed but varied significantly between treatment ($P<0.05$). In both breeds the PCV started to drop 3 weeks post-infection reaching its lowest level of 20% in 4^{th} week post infection in the Red Sokoto, and 6^{th} week in the Sahelian. For the control group with an initial mean PCV of 27%, the recorded PCV was 24% at the end of the study showing a difference of 3%. The corresponding drop in PCV values for the low and high level infection group were 8.1% and 11.6% respectively.

The PCV values of goats given high level of infection did not differ significantly from those of goats on lower infection level throughout the experiment. Overall, the PCV of the infected animals did not differ significantly from those of the control animals throughout the experiment.

Table 9: Changes in Packed Cell Volume (%) of growing Red Sokoto and Sahelian goats infected with *H. contortus.*

Week PI	Red Sokoto						Sahelian					
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff
0	26.6		25.4		30.5		27.4		28		36	
1	26.6	0	24.6	-0.8	30.2	-0.3	26.7	-0.7	28	0	36	0
2	19.4	-7.2	20.8	-4.6	22.5	-8	24.2	-3.2	22.9	-5.1	26.3	-9.7
3	21.4	-5.2	20.3	-5.1	19.8	-10.7	22.8	-4.6	20.7	-7.3	22.3	-13.7
4	22.4	-4.2	19.2	-6.2	21.8	-8.7	22.5	-4.9	19.6	-8.4	20	-16
5	22.1	-4.5	21.4	-4	21.3	-9.7	22.5	-4.9	19.6	-8.4	19.5	-16.5
6	22.1	-4.5	23	-2.4	17.5	-13	22.3	-5.1	20.2	-7.8	17	-19
7	22.4	-4.2	20.6	-4.8	17.1	-13.4	26.1	-1.3	20.2	-7.8	21.3	-14.7
8	21.8	-4.8	17.6	-7.8	24.8	-5.7	24.9	-2.5	19.6	-8.4	19.5	-16.5
9	23.5	-3.1	19.3	-6.1	23.7	-6.8	24.2	-3.2	20.6	-7.4	19.5	-16.5
10	23.6	-3.0	22.7	-2.7	23.6	-6.9	24.6	-2.8	20.3	-7.7	19.8	-16.5
Mean	22.8^{a}		23.6^{ab}		23.5^{a}		24.4^{a}		21.9^{b}		23.7^{a}	
SE	2.32		2.36		2.34		2.41		2.24		2.48	

4.3.4 Serum proteins

The mean total protein values for the infected Sahelian goats were significantly (P>0.05) higher than the pre-infection value of 49.9g/dl from week 4 of the infection. For the Red Sokoto goats, the total protein values during the infection did not differ significantly from the pre-infection value except during weeks 9 and 10 of the infection. At these periods the increase in value was significant (P>0.05). The difference in total protein between the final and initial values were 4.1 and 12.7 for the Red Sokoto and Sahelian (Table 10) respectively, while for control, low and high level of infection, the differences were 2.3, 21.4 and 1.6 respectively. The means of 63.3, 59.8 and 61.6 g/dl were not significantly different for control, low and high level infection groups.

Table 10: Least squares mean of Total protein (g/dl) of growing Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian					
	0	diff	$75L_3$	diff	$100L_3$	diff	0	diff	$75L_3$	diff	$100L_3$	diff
0	75.4		65.4		62.2		43.4		40.2		64.2	
1	65.4	-10	56.4	-9	58.6	-3.6	41.0	-2.4	39.2	-10	60.4	-3.8
2	71.6	-3.8	53.6	-11.8	61.8	-0.4	56.0	12.6	50.6	10.4	48.4	-15.8
3	67.8	-7.6	67.8	2.4	62.8	0.6	59.0	15.6	62.0	21.8	57.0	-7.2
4	62.0	-13.4	62.4	-3	60.8	-1.4	63.3	19.9	58.4	18.2	66.4	2.2
5	63.2	-12.2	61.6	-3.8	63.6	1.4	59.8	16.4	55.6	15.4	57.6	-6.6
6	65.4	-10	65.8	0.4	63.4	1.2	61.3	17.9	54.2	14.0	62.4	-1.8
7	66.0	-9.4	64.2	-1.2	66.1	3.9	64.5	21.1	52.2	12.0	57.8	-6.4
8	63.8	-11.6	58.8	-6.6	63.9	1.7	67.8	24.4	56.0	15.8	55.8	-8.4
9	63.6	-11.8	77.9	12.5	64.1	1.9	62.0	18.6	60.4	20.2	58.1	-6.1
10	64.5	-10.9	79.6	14.2	64.4	2.2	62.0	18.6	59.8	19.6	58.4	-5.8
Mean	66.4^{a}		64.7^{a}		62.9^{a}		60.7^{ab}		54.8^{b}		60.4^{ab}	
SE	5.83		5.61		7.15		6.09		5.29		6.21	

Similarly, the mean albumin values for the Sahelian goats were higher than the pre-infection values of 20.9g/dl (Table 11). The difference in value was significant from week 2 of the infection. In the case of the Red Sokoto goats the albumin value during the infection differed from the pre-infection value of 30.7g/dl. The difference in value which was significant was only at week 2 of the infection. The differences in initial and final mean albumin concentration during the study were -2 and 9 for Red Sokoto and Sahelian breeds, (Table 11) while the difference obtained for the infection levels were -2.1, 7.4 and 5.3gm/dl for control, low and high infection respectively.

Table 11: Least squares mean of Albumin concentration (g/dl) of growing Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian					
	0	diff	$75L_3$	diff	$100L_3$	diff	0	diff	$75L_3$	diff	$100L_3$	diff
0	33.2		28.4		29.8		20.9		18.2		21.4	
1	51.0	17.8	40.2	11.2	46.6	16.8	37.0	16.1	37.8	19.6	29.8	8.6
2	32.8	-0.4	30.9	2.5	33.8	4	33.0	12.1	27.6	9.4	27.0	5.6
3	33.4	0.2	36.2	7.8	34.6	4.8	32.5	11.6	30.2	12	35.8	14.4
4	31.2	-2	32.0	3.6	32.4	2.6	35.5	14.6	27.4	9.2	27.8	6.4
5	30.8	-2.4	31.8	3.4	31.8	2	26.3	5.4	21.8	3.6	30.6	9.4
6	31.0	-2.2	31.8	3.4	39.2	9.4	34.5	13.6	23.2	5	26.6	4.4
7	31.8	-1.4	30.0	1.6	23.8	-6	29.8	8.9	25.0	6.8	26.0	4.6
8	26.0	-7.2	31.4	3	27.1	-2.7	24.3	3.4	30.6	12.4	34.2	12.8
9	26.0	-7.2	32.8	4.4	27.3	-2.5	24.3	3.4	30.4	12.2	34.1	12.7
10	26.3	-6.9	32.8	4.4	27.2	-2.6	24.5	3.4	30.2	12	34.5	13.1
Mean	32.7^{a}		32.5^{a}		32.6^{a}		29.8^{b}		27.2^{b}		29.3^{b}	
SE	3.30		3.49		4.48		3.79		3.30		3.86	

Also, the mean globulin values for the Sahelian goats were lower (P>0.05) throughout the experiment than the pre-infection values of 33.49g/dl (Table 12). The difference in value was significant (P>0.05) from week 2 of the infection. For the Red Sokoto goats, the globulin value during the infection differed from the pre-infection value of 34.6gm/dl. The difference in value which was significant was at week 2 of the infection. The recorded difference in the initial and final mean globulin concentrations were 6.1 and 4.6, for Red Sokoto and Sahelian (Table 12) goats, and 5, 13.8 and -3.1gm/dl for control, low and high levels of infection respectively.

Table 12: Least squares mean of globulin concentration (g/dl) of growing Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian					
	0	diff	$75L_3$	diff	$100L_3$	diff	0	diff	$75L_3$	diff	$100L_3$	diff
0	42.3		28.7		32.9		33.5		21.3		44.7	
1	42.2	-0.1	28.0	-0.7	32.4	-0.5	33.3	-0.2	21.0	-0.3	44.3	-0.3
2	14.4	-27.9	13.4	-15.3	14.4	-18.8	19.0	-14.5	12.8	-8.5	18.6	-26.1
3	38.8	-3.2	37.4	8.7	28.0	-4.9	26.0	-7.5	34.4	13.1	30.0	-14.7
4	34.4	-7.9	26.2	-2.5	28.2	-4.7	30.7	-2.8	28.2	6.9	30.6	-14.1
5	30.8	-11.5	29.6	0.9	31.8	-1.1	24.3	-9.2	28.2	6.9	29.8	-14.9
6	32.4	-9.9	34.0	5.3	24.2	-8.7	31.4	-2.1	32.4	11.1	31.8	-12.9
7	34.4	-7.9	32.4	3.7	36.9	4	30.0	-3.5	32.4	11.1	31.2	-13.5
8	34.4	-7.9	28.8	0.1	37.0	4.1	38.0	4.5	29.0	7.7	29.8	-14.9
9	37.8	-4.5	49.5	20.8	36.6	3.7	37.8	4.3	28.8	7.5	29.1	-15.6
10	37.6	-4.7	49.6	20.9	36.8	3.9	37.6	4.1	29.4	8.1	29.1	15.6
Mean	33.7^{a}		32.9^{a}		29.5^{b}		30.8^{ab}		27.6^{b}		30.4^{ab}	
SE	4.41		4.77		5.16		5.07		4.41		4.43	

4.4.0 Experiment IV

4.4.1 Weight change

The effect of *H. contortus* infection on weight in lactating Red Sokoto and Sahelian does is presented in Table 13. There was no difference (P>0.05) in the mean weight for the different infection levels. The mean weight for the Red Sokoto where 26.0, 25.0 and 29.4 for control, low and high infection levels during the experimental period respectively. The value for the Sahelian *does* in the control and low infection groups were 22.4 and 25.5kg respectively. Both infection level and breed did not significantly (P>0.05) affect weight change in does. Red Sokoto goats infected with *H. contortus* at low and high levels had a mean gain of 15.2 and 11.2g/day; while the Sahelian does infected with low level of *H. contortus* had a corresponding value of 24.5g/day. The corresponding value for the control animals was 30.0g/day. Overall the Sahelian does (infected/non-infected) involved in this experiment had a mean ADG of 30.0g/day compared to 17 ± 8.9g/day for the Red Sokoto goats.

Table 13: Weight changes (kg) and ADG (g/day) of Lactating Red Sokoto and Sahelian goats experimentally infected with *H. contortus.*

Week PI	Red Sokoto						Sahelian					
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff	PI	
0	25.3		28.4		24.0		20.9		27.1			
1	25.3	0	28.2	-0.2	24.1	0.1	21	0.1	27.3	-0.2	0.4	
2	25.5	0.2	29.9	1.5	24.5	0.5	23.9	3	27.0	-0.1	1.9	
3	25.2	-0.1	30.2	1.8	24.6	0.6	23.6	2.7	24.5	-2.6	3.9	
4	25.4	0.1	29.3	0.9	25.4	1.4	22.2	1.3	27.3	0.2	1.1	
5	25.9	0.6	29.5	1.1	25.1	1.1	22.5	1.6	24.9	-2.2	2.1	
6	26.7	1.4	29.9	1.5	25.2	1.2	22.9	2	25.0	-2.1	3.1	
7	26.4	1.1	29.0	0.6	25.0	1	21.9	1	27.1	0	1.8	
8	26.6	1.3	29.7	1.4	25.6	1.6	22.6	1.7	25.9	-1.2	2.5	
9	26.6	1.3	29.2	0.8	25.0	1	22.7	1.8	26.3	-0.8	2.5	
10	25.3	0	29.5	1.1	25.5	1.5	23.3	2.4	25.7	-1.4	2.5	
Mean	26.0		25.0		29.4		22.4		25.5			
SE	6.67		5.97		6.67		6.67		5.97			
ADG	26.8		15.2		11.2		37.8		24.5			

4.4.2 Faecal egg count

Table 14 shows the result of the faecal egg count. There was no significant difference (P>0.05) in the faecal egg count between breed, Rather, the difference (P>0.05) was between infection levels. The Sahelian showed a peak FEC of 4180 eggs per gram by week 2 post infection while the corresponding FEC for the Red Sokoto goats was 8 eggs per gram. However, the peak for the Red Sokoto (672eggs per gram) was attained 4 weeks post infection (Table 15). The faecal egg count was influenced by the infection levels (P<0.05); goats on the low infection level had the highest FEC of 984.3±161.8 eggs per gram for the Sahelian goats while for the same treatment group the Red Sokoto had a FEC of 172.1±161.82 eggs per gram. The high infection group of the Red Sokoto goats received higher dose of larvae but had a lower mean epg (431.5±181.48 eggs per gram) than the Sahelian (984.3 ±161.82) of a low infection group.

Table 14: Least squares mean of untransformed epg of lactating Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto			Sahelian	
	0	$75L_3$	$100L_3$	0	$75L_3$
0	0	0	0	0	0
1	0	0	28	0	20
2	0	8	26	0	4180
3	0	12	20	0	200
4	0	16	1645	0	3192
5	0	164	420	0	1192
6	0	672	965	0	408
7	0	268	762	0	1612
8	0	336	320	0	292
9	0	72	600	0	532
10	0	196	435	0	536
Mean	0.9	172.1	431.5	0.7	984.3
SEM	646.11	653.80	577.90	646.11	583.15

Table 15: Least squares mean of log_{10} epg lactating Red Sokoto and Sahelian goats infected with three levels of *H. contortus.*

Weeks PI	Red Sokoto				Sahelian
	0	$75L_3$	$100L_3$	0	$75L_3$
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0.3	0.6	0	0.7
3	0	0.3	0.5	0	1.5
4	0	0.6	3.0	0	1.3
5	0	1.4	2.4	0	3.2
6	0	2.6	2.9	0	2.9
7	0	2.3	2.7	0	2.5
8	0	2.4	1.9	0	2.4
9	0	0.9	1.9	0	2.2
10	0	1.4	2.4	0	2.1
Mean	0	1.3	1.6	0	1.9
SEM	0.37	0.37	0.32	0.37	0.33

4.4.3 Milk yield and composition

The average daily milk yield did not differ significantly (P>0.05) between the two breeds (P>0.05). Irrespective of treatment, the Sahelian recorded a higher yield (307.0±35.8) than the Red Sokoto (212.4±12.6). In the Red Sokoto does, the milk production fell below the pre-infection level from week 5 post infection till the end of the experiment (Table 16). The Sahelian showed a sharp drop below pre-infection level by one and a half weeks of infection after which there was a gradual rise to a peak of 327.8±44.9 at week five and a half. Thereafter, the production was below the pre-infection level. Irrespective of the infection level, parity also played a significant role (P<0.05) on the milk produced by goats. The goats that were in their 3rd lactation produced more (P>0.05) (339.9ml/day) milk than those that were in their 2nd (250.4ml/day) and 1st (189.6ml/day) lactation. There was no difference (P>0.05) in the chemical composition for breed and treatment. The total solid ranged from 13.2 to 14.2 %, the percentage fat had a mean of 2.5%, while the protein was also within the range of 4.1%.

Table 16: Changes in milk yield (ml) of lactating Red Sokoto and Sahelian goats infected with *H. contortus.*

Week PI	Red Sokoto						Sahelian			
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff
0	175		200		290		268.8		390	
1	175	0	200	0	290	0	268.8	0	390	0
2	155	25	295	95	247	-43	140	-128.8	264	-26
3	155	75	285	85	236	-54	185	-83.8	230	-60
4	137.5	-22.5	316.3	116.3	282	-8	202.5	-66.3	249	-41
5	137.5	-25	316.3	116.3	282	-8	202.5	-66.3	249	-41
6	162.5	-10	283.8	83.8	362	72	181.3	-87.5	385	-5
7	212.5	37.5	262.5	62.5	306	16	266.7	-2.7	310	-80
8	160	-15	253.8	53.8	244	-46	123.7	-145.1	313	-73
9	112.5	-62.5	267.5	67.5	194	-96	165	-103.8	325	-65
10	127.5	-47.5	192.5	-7.5	227	-63	157.5	-111.3	334	-54
11	113.1	-61.9	232.5	32.5	213.5	-76.5	135	-133.8	248	-142
12	112.5	-62.5	217.5	17.5	194	-76	140	-128.8	255	-145
13	122.5	-52.5	252.5	52.5	215	-75	128.8	-140	265	-125
14	102.5	-72.5	202.5	2.5	406	116	127.5	-141.3	260	-130
15	108.8	-66.5	202.5	2.5	184	-106	117.5	-151.3	251	-131
16	118.8	-56.5	243.7	43.7	210	-80	1000	-168.8	251	-131
17	125.8	-49.2	280	80	184	-106	150	-118.8	212.5	-177.5
18	75.5	-99.5	235	35	180	-110	135	-133.8	256.5	-124.5
19	75	-100	238	38	180	-110	130	-138.8	260	-130
Mean	136.2		249.4		244.4		167.1		282.5	
SE	23.11		23.11		20.67		23.01		20.66	

4.4.4 Packed Cell Volume

The results for the Packed Cell Volume are presented in Table 17. The PCV was not significantly influenced by breed ($P>0.05$) but by treatment ($P<0.05$) (Fig 20). Both breeds showed significant ($P<0.05$) drop in PCV by week 2 of infection. For the Sahelian, the initial PCV dropped by 42% while for the Red Sokoto it dropped by 33%. For both breeds, the highest mean PCV after infection was attained by week 3, by which time the Sahelian had a value of 31%, and the Red Sokoto a value of 26%. These values were nonetheless lower than the pre-infection values. By the end of the experiment at week 11, the mean PCV for the Sahelian and Red Sokoto breeds were 24% and 23% respectively. These values were 55% and 66% of their respective pre-infection values. Overall values of the infected does ($75L_3$/kg) were significantly higher than the values for control does at weeks 2, 6 and 7 of the infection.

Table 17: Changes in Packed Cell Volume (%) of lactating Red Sokoto and Sahelian goats infected with *H. contortus.*

Week PI	Red Sokoto						Sahelian			
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff
0	35.6		31.7		32.4		38.7		41.6	
1	35.5	-0.1	31.7	0	32.4	0	38.5	-0.2	41.6	0
2	31	-4.6	26.8	-4.9	22.4	-10.2	25.2	-13.2	23	-18.6
3	28.6	-7.0	26.5	-5.2	24.4	-8.7	31.7	-6.7	25.8	-16.8
4	26.3	-9.3	24.8	-6.9	23	-9.4	27.8	-10.7	25.6	-16
5	25	-10.6	24.3	-7.4	24.6	-7.8	27.5	-11.2	26	-15.6
6	24.5	-10.1	20	-11.7	20.8	-11.6	25.2	-13.5	20.8	-20.8
7	25.3	-10.3	24.5	-7.2	20.2	-12.2	24.3	-14.4	20	-21.6
8	26.5	-9.1	23.5	-8.2	23	-9.4	26.3	-12.7	25.6	-16
9	23.3	-11.3	20.8	-10.9	21.8	-10.6	23.5	-15.2	23.8	-17.8
10	25	-10	21.8	-9.9	23.2	-9.2	22.8	-15.9	24.4	-17.2
Mean	27.1[a]		24.3[a]		23.4[a]		27.6[a]		25.2a	
SE	5.84		5.86		5.24		5.86		5.25	

4.4.5 Serum proteins

The mean value for the total protein is presented in Table 18. The mean total protein values for the Sahelian does were lower than the pre-infection level of 70.6g/dl. The difference in value was significant (P>0.05) from week 3 post infection. For the Red Sokoto does, the total protein value was also lower than the pre-infection value. The difference in value for the Red Sokoto was significant as from week 2 of the infection (Table 18).

Table 18: Least squares mean of Total protein (g/dl) of lactating Red Sokoto and Sahelian goats infected with different levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian			
	0 L_3/kg	diff	75L_3/kg	diff	100L_3/kg	diff	0L_3/kg	diff	75L_3/kg	diff
0	72.5		65.8		85.7		69.3		71.2	
1	72.3	-0.2	65.5	-0.3	85.5	-0.2	69.4	1	71.0	-0.2
2	67.7	-4.8	58.3	-7.5	66.7	-19	69.3	0	54.0	-12.2
3	59.3	-13.8	61.7	-4.1	62.6	-23.1	57.5	-11.8	65.5	-5.7
4	64.3	-8.2	54.3	-11.5	54.8	-30.9	61.7	-7.6	68.2	-3
5	57.0	-15.5	61.0	-4.8	62.0	-23.7	64.8	-0.5	72.4	1.2
6	62.3	-10.2	69.8	4	66.0	-19.7	66.3	-3	64.0	-7.2
7	58.5	-14	65.5	-0.3	60.6	-25.1	61.8	-7.5	66.8	-4.4
8	63.0	-9.5	65.3	-0.5	59.8	-23.1	65.0	-4.3	65.8	-5.4
9	63.0	-9.5	60.0	-5.8	62.3	-23.4	65.0	-4.3	65.8	-5.4
10	63.3	-9.2	60.0	-5.8	62.3	-23.4	71.5	2.2	66.0	-5.2
Mean	63.1 [a]		62.1[ab]		64.3 [a]		65.4 [a]		65.9[a]	
SE	4.21		4.31		3.96		4.09		3.67	

Similarly, the mean albumin concentration was significantly influenced ($P<0.05$) by breed and treatment. The Sahelian had a higher albumin concentration (35.7±0.99g/dl) than the Red Sokoto (33.7±0.56g/dl) (Table 19). Also, the mean albumin concentrations for the control, low and high infection groups irrespective of breed were 35.7±0.70, 33.3±0.66 and 34.9±g2.88m/dl respectively. Both breeds showed a drop in the mean albumin concentration by week 2 post-infection (Table 19). The Sahelian suffered a drop of 30% from the initial pre-infection value while the Red Sokoto experienced a 26% drop within the same period. For both breeds the pre-infection values were never attained except for the rise observed in week 5. By the end of the experiment at week 10 the mean albumin concentration for the Sahelian and Red Sokoto were 28.8 and 28.9 g/dl representing 57 and 54% of the respective pre-infection values.

Table 19: Least squares mean of Albumin concentration (g/dl) of lactating Red Sokoto and Sahelian goats infected with Different levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian			
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff
0	52.5		49.7		58.6		52.5		49.0	
1	52.3	-0.2	49.0	-0.7	58.3	-0.3	52.1	-0.4	49.3	3
2	37.3	-15.2	40.3	-9.4	41.3	-17.3	35.0	-17.5	36.0	-13
3	32.3	-20.2	27.3	-22.4	36.0	-22.6	34.0	-18.3	34.3	-14.7
4	32.3	-20	26.5	-23.2	28.4	-30.2	33.8	-18.7	33.0	-16
5	31.7	-20.8	25.3	-24.4	27.3	-31.2	37.8	-14.7	33.4	-15.6
6	29.8	-22.7	30.0	-19.4	36.5	-22.1	33.5	-19	33.2	-15.8
7	28.3	-24.2	33.5	-16.2	33.4	-25.2	33.0	-19.5	31.0	-18
8	26.3	-26.2	29.7	-20	28.5	-30.1	39.5	-13	32.6	-16.4
9	28.8	-23.7	29.7	-20	28.5	-30.1	39.5	-13	29.4	-19.6
10	28.9	23.6	28.7	-20	28.6	-30	39.4	-13.1	29.5	-19.5
Mean	33.8 [ab]		32.5[b]		34.9 [a]		37.2[a]		34.1 [a]	
SE	3.19		3.19		2.88		3.13		2.68	

Table 20 also shows the mean concentration of serum globulin. There was no significant difference ($P<0.05$) for both treatment and breed. Nonetheless, it was observed that the Sahelian had a higher globulin concentration (31.8±1.21g/dl)than the Red Sokoto goats (29.4±0.73g/dl) (Table 20). The mean globulin concentrations for the control, low and high infection group irrespective of breed were 30.7±0.86 and 29.3±3.58, 28.7±0.92g/dl respectively. The globulin concentration showed gradual rise in both breeds. The highest mean globulin concentration was attained for both at the end of the experiment in week 10. The mean globulin concentration for the Sahelian and Red Sokoto breeds were 34.5 and 32.9g/dl respectively. These values were 176 and 154% of their respective pre-infection values.

Table 20: Least squares mean of globulin concentration (g/dl) of lactating Red Sokoto and Sahelian goats infected with Different levels of *H. contortus.*

Weeks PI	Red Sokoto						Sahelian			
	$0L_3$/kg	diff	$75L_3$/kg	diff	$100L_3$/kg	diff	$0L_3$/kg	diff	$75L_3$/kg	diff
0	20.3		17.5		27.8		17.2		22.8	
1	20.0	-0.3	16.5	-1	27.5	-0.3	16.7	0.5	22.2	0.6
2	30.5	10.2	18.0	0.5	25.3	-2.5	22.5	5.3	18.6	-4.2
3	27.0	6.7	34.3	16.8	26.6	-1.2	27.7	10.5	30.3	-7.5
4	32.0	11.7	27.8	10.3	26.6	-1.2	31.0	13.8	32.4	9.6
5	25.3	5.3	35.7	18.2	26.4	-1.4	28.5	11.3	34.5	11.7
6	32.5	12.2	39.8	22.3	34.6	6.8	28.3	11.1	39.2	16.4
7	30.3	10	31.5	14	29.5	1.7	31.5	14.3	33.0	10.2
8	26.7	6.4	31.5	14	27.2	-0.6	32.0	14.8	34.2	11.4
9	34.3	14	30.3	12.8	28.8	1	32.0	14.8	36.4	13.6
10	34.5	14.2	30.3	12.8	33.8	6	31.3	14.1	29.4	6.6
Mean	29.3		29.6		29.4		28.2		31.8	
SE	3.29		3.86		3.54		3.84		3.29	

5.0 DISCUSSION

5.1 Experiment I

The milk yield recorded in this study for both breed is below that reported by Ehoche and Buvanendran (1983), Djibrillou *et al.* (1998), Cisse *et al. (*2002) Greyling *et al*. *(2004*) but similar to that reported by Tedonkeng Pamo *et al*. (2006) where West Africa Dwarf does were fed multipurpose leguminous tree leaves.

This difference in milk yield in this present study may be explained by the difference in method of milk collection and the type of breeds used. In the study of Ehoche and Buvanendran (1983) oxytocin was administered to the dams prior to milking, which could have greatly enhanced the milk expressed from the udder. Djibrillou *et al.* (1998) used weighing of the kid before and after milk intake to obtain milk yield by the difference, while Greyling *et al.* (2004) used improved breeds of goats. Prasad and Sengar (2002), Mia *et al.* (1994) and Eknaes *et al.* (2006) in their separate studies showed that genetic make-up and nutritive intake of different breeds of goats greatly influenced the milk yield and its composition. The maize stover provided to the dams was of low quality, which might have required treatment to provide the available nutrient that will support production (Makun *et al.*, 2001). The poor digestibility of maize stover may therefore have limited the nutrients available to the does to support high milk production.

The differences in kid weight between the two breeds in this study may be more a function of the maternal characteristics of the does as has been reported earlier by Gooonewardene *et al.* (1999) than kid performance since preweaning growth depicts the quality and quantity of milk available to the kids. The Sahelian kids are larger-boned animals which gives them an advantage of

heavier weight over and above Red Sokoto kids which are medium-boned animals (Mavrogenis and Papachristoforou 2000). There was a general loss in body weight in the two breeds, and the rate of weight loss was similar in both breeds. The loss in body weight could generally be attributed to mobilization of the body fat that has been stored during the dry period. It is believed that an estimated 64g/day is lost from day 11 to 37 postpartum (Eknaes *et al.* 2006), but in this present study the weight loss was persistent throughout the lactation probably due to the fact that maize stover could not supply the required energy to support milk production, leading to mobilization of body protein and fat to sustain milk production.

The mean values of milk fat and milk solid of the goat in the present study were similar to those earlier reported (Prasad and Sengar 2002; Greyling *et al.*, 2004), where the milk fat increased with advancing lactation. They however contrast with the reports of Djibrillou *et al.* (1998) and Eknaes *et al.* (2006) where milk fat decreased with advancing lactation.

The persistent milk production in spite of the poor quality roughage may have caused the weight loss, since the protein stored in the body may be channeled into energy for milk production through gluco-neogenesis (Eknaeas *et al.*, 2006). It will therefore seem that the goats in this study although receiving low quality roughage were able to sustain milk production through mobilization of body reserves in the form of protein and fat. This is evident by the fact that up to the end of the experiment, the does were not able to return to their initial weight after kidding.

5.2 Experiment II

The results of this study have shown that the male kids of both breeds were born heavier than their respective females and this corroborates the reports of Pfeffer and Rodehutscord (1998).

The males of both breeds also grew faster than the females, lending credence to the earlier work of Al-Nakib *et al*. (1996) and Santra and Karim (1999). Even though the Sahelian kids were heavier at birth and consumed more feed, the postweaning growth rate was faster in the Red Sokoto kids, to the extent that their weaning weights were comparable. This could possibly be due to the inherent breed differences or environmental adaptation as have earlier been reported (Tauh *et al.,* 2005). The Sahelian breed is found in the arid regions where they thrive better. In the Savannah where the study was carried out, they probably adapted and thrived less than the indigenous Red Sokoto goats. In the arid regions the Sahelian goats feed on browses and shrubs, which usually contain more protein and are available all year round to support them during the dry spells (Aganga and Monyatsiwa, 1999; Papachritou *et al.* 1999). The Red Sokoto goats are already adapted to this Guinea Savanna so that even when they consume less feed they are able to utilize it for maximum gains, while the Sahelian may not have fully adjusted for that benefit from the available feeds. The works of various scientists demonstrate that browses and shrubs are able to sustain and improve goat productivity in the arid regions (Hatendi *et al.* 1992; Ahmed and Nour, 1997; Aganga and Monyatsiwa, 1999 and Papachristou *et. al.*, 1999).

It can be inferred that the Sahelian breeds of goats can adapt and thrive in the northern Guinea Savanna zone of Nigeria. The heavier birth weight of the Sahelian kids can be harnessed in breeding programmes with regards to crossing with other breeds.

5.3 Experiment III

The results of experiment III showed difference between the Sahelian and the Red Sokoto in their susceptibility to trickle infection with *H. contortus*. The faecal egg count (FEC) was higher and more sustained in the Sahelian than in the Red Sokoto. This high and sustained faecal egg count may be partly due to the inability to development of resistance in the Sahelian. The FEC with all its limitation is usually an index to determine the resistance or otherwise of within and between breeds (Waller, 1993) and evidence abound to suggest that it is usually a heritable and repeatable traits which can be of value in selective breeding for helminth resistance (Pralomkran *et. al.* 1997, Kahn *et. al.,* 2003). The result of the present study is comparable to the work of Baker *et. al.* (1998), who demonstrated that 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 work by Mugambi *et. al.* (1997) showed that sheep also exhibit resistance between breed, they showed that the black-headed Dorper Somalian sheep was more susceptible to *H. contortus* on the basis of its higher egg count and lower PCV than the Red Masai sheep.

The significantly higher faecal egg count in the present study by the Sahelian breeds of goats was accompanied by a more drastic reduction in PCV after infection, as compared to the reduction of the PCV in the Red Sokoto. In the Red Sokoto, there was a drop from 27% to 21%, compared to that of the Sahelian was from 30% to 21%. This slightly higher drop in PCV, which is an evidence of anaemia, demonstrated the fact that the Sahelian does were less capable of containing the infection (Abbot *et al.*, 1985).

Hypoproteinaemia is a common feature of parasitic infection (Pawa and Gathe 2004), and this present study showed that both breeds of goats show reduced serum protein level at the beginning of the study, but greatly improved as the experiment progressed. This finding is in contrast with the work of Mugambi *et al.* (1996), where total protein increased, but lent support to that of Abbot *et al.* (1985) and Haile *et al.* (2002) where the finn Dorset lambs showed no change in serum protein. This may be due to the higher protein levels fed to the experimental animals in this present study. A diet of 16% crude protein CP has been recommended to be adequate for goats, to provide the necessary ingredients for immune response to the infection. (Blackburn *et al.* 1991)

The protein content plays an important role particularly in growing animals like those in this experiment, since protein is very essential for the growth and development of weaned animals, (Santra and Karim 1999). It therefore follows that the body will have to compete with the helminths for nourishment, especially for protein since these helminths suck blood and protein is the major constituent in blood (Knox and Steel, 1996). In this experiment the animals were post-weaned kids requiring protein for growth and defence against the experimental infection. However, the dietary protein provided (20%) was beyond the recommended (16%) protein in the diet, thus providing adequate nutrition to protect against the devastating effect of the parasite. This is inferable from the increase in the total protein and serum globulin recorded during the experiment. It had earlier been suggested (Kyriazakis *et al.*, 1994) that lambs that were supplemented were able to better withstand the pathogenic effect of infection by maintaining high serum protein and PCV than unsupplemented lambs. Also, the increase in globulin concentration may be linked to immune response of the animals to infection. Globulin has been

shown to contain immunoglobulin which is necessary for defence against parasitic infection. Kyriazakis *et al.* (1996); Balic *et al.* (2002) and Abrahams-Sandi *et al*. (2005) demonstrated an increase in both cellular and humoral response following helminthic challenge, which go on to support the increase the serum globulin in this current study. Therefore, it can be deduced that these responses in this present study may be an immunological response (Gomez-Munoz et al. 1999) against the *H. contortus* challenge.

It is pertinent to note that the Red Sokoto were able to tolerate *H. contortus* infection because they exhibited high PCV, total protein, serum globulin, weight gain and lower faecal egg than the Sahelian. Generally the 2 breeds were able to condone the infection without any significant weight loss. This is similar to the work of Chiejina *et al.* (2002), who did not observe any weight loss in the West African Dwarf (WAD) goats infected with the local strain of *H. contortus* at between 260-450L_3/kg. The WAD were able to develop protective immunity which was expressed by mild changes in the PCV, little or no effect on the weight changes, but when in an earlier study they (Fakae *et al.* ,1999) used an exotic strain of the helminth, the response was severe anaemia and weight loss were observed.

The weight gain in this present trial does not depict the normal weight change for these breeds of goats within this ecological zone, as Makun *et al.* (2006) had recorded a higher average daily gain of 66g/day and 40g/day for the Red Sokoto and Sahelian kids respectively within the same experimental environment. Therefore, the present average daily gain of 13 and 2g/day is below that for the Red Sokoto and Sahelian respectively fed the same diet. Hence it is inferable that the lower weight gain was due to the deleterious effect of the *H. contortus*.

It has been reported that following infection with helminths there is usually a 10% reduction in voluntary feed intake and a 30% decrease in live weight gain (Kyriazakis *et al.,* 1994) but the host circumvent this by making selection between available and appropriate feeds to maintain its requirements. In their study Kyriazakis *et al.* (2002) showed that even though *T. colubriformis*-parasitized lambs had reduced voluntary feed intake, the parasitised lambs were through selecting their diet between the low, medium and high protein diet able, to consume more protein to obtain similar live weight as the control lambs. It therefore goes to show that since the CP in the present study was above the recommended CP, the goats in the study may not have suffered any lack of protein, which is considered the most limiting ingredient in most livestock diet in developing countries. (Devendra, 1999).

5.4. Experiment IV

The mean weight of lactating does did not vary significantly, even though the Sahelian had a higher mean weight. The higher weight of the Sahelian does is most likely to be due to the fact the Sahelian breeds has larger bones than the Red Sokoto as reported by Makun *et al.* (2006). Also, the mean weights for the two infection levels were not statistically different although those in the low infection levels had a higher mean weight than the high infection groups. This contradicts the findings of Kyriaisazis *et al.* (1996) where goats that were on high level of infection were more affected that those on the low level or control. In this study, the animals that were in the control group were mostly primiparous animals, in their first lactation. Eknaes *et al.* (2006) reported that dairy animals usually mobilized their body reserves to sustain milk

production in early lactation and that this was more pronounced in animals that were in the first lactation.

The high mean weight in the low infection group as compared to the high infected group is likely to be due to the fact that those on the high infection level not only produced milk for their kids but also had to cope with higher parasitic infection level. Also, only the Red Sokoto were represented in the high infection group and since the Sahelian are larger, their heavier weight might have further contributed to the high mean weight in the control and low infection groups over those in the high infection group. Although the average daily gains did not vary between the levels of infection or breed, the Red Sokoto goat had higher average daily gain than the Sahelian goats. In a similar study, Baker *et al*. (1998) reported that the Small East African goats showed higher liveweight than the Galla goats. The infection with *H. contortus* affects the requirement of the animal; as the goat has to respond to the challenges of milk production, defence against parasitic infection, by depleting its body reserves to ensure survivability of the kids. As in the mean weight, the average daily gain in the low infection group was lower than in the high infection group, although, the Sahelian are larger, their heavier weight might have further contributed to the higher mean weight seen in the control and low infection groups

The faecal egg count expressed as eggs per gram (epg) of faeces, was influenced significantly by infection levels and breed. The Sahelian also had higher faecal egg count than the Red Sokoto as was the case in experiment I, although the egg count was lower than in experiment III. This suggests that the Sahelian were unable to tolerate the parasite, as indicated by higher excretion of egg in faeces. The ability to control parasitism by manipulation of the host minimizes response, varies between breeds (Abbott, Parkins and Holmes, 1986). This phenomenon has been reported

by Baker *et al.* (1998); Chiejina *et al*. (2002) and Rege *et al*. (2002) who showed that there was usually breed variation in the faecal egg output. Chiejina *et al*. (2002) showed that the West African Dwarf goat in Nigeria were able to express better immunity when local rather than an exotic isolate was used for experimental infection (Fakae *et al.* 1999). Therefore, the environment and host interaction play a significant role in acquisition of immunity against a particular infection. It is only when there is a shift to an extent that the parasite overcomes the immune system that production parameters become affected.

In this experiment, the milk yield was influenced by infection levels and parity of the goats. Milk yield was higher, though not significantly, in the Sahelian than the Red Sokoto breed. The control does were expected to produced more milk than the groups with low or high infection level. This was not the case in this study. This aberration may be attributed to the fact that, since does were not blocked according to parity at the beginning of the experiment; those in the control group were in their 1^{st} lactation. Animals in their 1^{st} lactation normally produced less milk than those in their 2^{nd} or 3^{rd} lactation. Also, animals in the later lactation are older than those in the 1^{st} lactation and the older animals will be able to tolerate the infection making them better able to produce more milk than those in their 1^{st} lactation.

The packed Cell Volume (PCV) was similarly affected by infection levels and not breeds. All goats had a drop in their initial PCV before it rose again, but by the end of the experiment, the control still maintained a higher PCV than the other groups. This showed that the infection was responsible for the drop in PCV. Studies conducted earlier (Abbot *et al.,* 1986; Chiejina *et. al.*,

2002) showed that apart from the faecal egg count and worm burden, decrease in Packed Cell Volume was an indication of the pathology associated with haemonchosis.

The Red Sokoto had lower mean total protein and albumin compared to the Sahelian. Low serum protein has been shown to be an indication of the adverse effect of haemonchosis, Unlike the Red Sokoto goats, which were included in both levels of infection, the Sahelian were only included in the low level. This might have accounted for the observed lower mean total protein and albumin in the Red Sokoto goats. The mean globulin did not differ in both breeds, showing that the immune system was equally responsive in both breeds. It is also possible that the high protein diet may have reduced the negative effects of the infection since protein has been shown to reduce the pathopysiology of gastrointestinal parasitism. Charteir *et al.* (2000) demonstrated that goats that were fed high protein diet (25%) exhibited lower egg output and had significantly higher milk yield and fat content than those goats that were fed normal level of protein (16%). Therefore, the high protein level of 20.3% crude protein in this experiment as against the recommended 16% crude protein may have partially enhanced resilience of these goats (Hoste, *et. al.*, 2008).

CONCLUSION/RECOMMENDATIONS

The findings of this work reiterate the fact that the Sahelian kids are usually born heavier and their pre-weaning growth rate is faster than the Red Sokoto kids. This shows that the mothering ability of the Sahelian may be superior to that of the Red Sokoto dams; therefore they are able to sustain faster pre-weaning growth performance of the Sahelian kids. This finding also emphasizes the fact that male goat kids are always superior in growth performance compared to the female goat kids. The quantity of the milk produced by the Red Sokoto although not different from that of the Sahelian was of better quality in terms of high total solids and fat, which indicates that the milk from the Red Sokoto does, may be more appropriate for production of milk products like yoghurt, butter and cheese.

The post-weaning growth performance of the Red Sokoto kids was more superior to that of the Sahelian. This shows that the Red Sokoto kids in this study have adjusted more favourably to the Northern Guinea Savanna than their Sahelian counterparts.

This superior performance of the Red Sokoto was further confirmed when they were infected with *Haemonchus contortus*, The Red Sokoto kid were able to relatively resist the infection compared to the Sahelian as indicated by the higher average daily gain, less severe anaemia indicated by higher mean Packed Cell Volume, lower faecal egg count. These findings go on to suggest that the Red Sokoto goats were more tolerant and therefore they may be important for breeding and selection using parasite as an indicator.

Following infection of lactating goats with *H. contortus*, the Sahelian still showed minimal resistance when compared to the Red Sokoto goats, because the Sahelian goats had higher faecal egg count, and more severe anaemia as compared to the Red Sokoto goats. The milk yield was not different between the two breeds. Fat content of the milk was severely affected by infection in both breeds of goats, showing that infection adversely affects the quality of milk. The findings also shows that the young goats were more severely affected than the adult goats, since the growing goats showed higher feacal egg count, lower daily gain, lower total proteins compared to the adults.

It is therefore recommended that further work needs to done to study the different immunological response of the Red Sokoto and Sahelian goats to understand the factors responsible for the higher tolerance level of the Red Sokoto compared to the Sahelian breeds of goats.

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Appendix 1. Weekly least square means of epg, PCV, total protein, albumin, globulin and weight changes of growing Sahelian and Red Sokoto kids infected with *H. contortus.*

Parameter												
	Week	1	2	3	4	5	6	7	8	9	10	SE
epg	Red Sokoto	3.5	165.3	579.3	1308.0	1258.5	1267.7	1152	1482.7	574.8	415.0	574.24
	Sahelian	90.7	435.1	2143.3	3393.3	3467	2392.8	1930.1	1791	2099.8	1629.8	551.99
PCV	Red Sokoto	28.5	27.8	21.1	20.9	21.2	22.1	21.6	22.7	20.7	24.0	1.29
	Sahelian	30.7	30.9	23.8	22.3	21.0	20.1	19.8	22.1	21.4	21.6	1.34
Mean weight	Red Sokoto	9.6	9.5	9.5	9.7	9.5	9.8	9.9	9.9	9.9	10.9	0.88
	Sahelian	13.4	13.2	12.9	12.9	12.4	12.7	12.9	12.9	12.6	12.8	0.91
Total protein	Red Sokoto	64.6	59.3	67.2	64.3	61.5	64.7	64.6	63.2	68.5	68.7	3.37
	Sahelian	49.9	51.3	58.4	62.4	57.9	59.8	58.7	60.6	63.0	62.6	3.38
Albumin	Red Sokoto	30.1	45.7	32.7	35.7	31.2	32.5	34.9	29.2	27.7	28.0	1.98
	Sahelian	20.1	34.9	29.2	32.8	30.2	26.2	28.1	26.9	29.7	29.6	2.04
Globulin	Red Sokoto	34.5	13.7	34.5	29.6	29.5	32.7	30.3	33.3	41.5	41.2	2.53
	Sahelian	32.9	16.8	30.1	29.6	27.4	31.9	30.1	32.9	32.2	32.1	2.59

Appendix 2. Weekly least square means of epg, PCV, total protein, albumin, globulin and weight changes of lactating Sahelian and Red Sokoto kids infected with *H. contortus.*

Parameter	Week	1	2	3	4	5	6	7	8	9	10	SE
Milk Yield	Red Sokoto	223.5	229.8	248.1	250.6	206.3	187.1	187.2	206.3	193.8	164.6	24.68
	Sahelian	412.6	286.1	305.1	327.8	318.1	313.6	276.4	276.9	271.7	256.4	43.72
PCV	Red Sokoto	27.5	27.1	20.9	20.5	21.1	21.6	20.8	22.6	21.0	23.3	1.39
	Sahelian	30.5	30.4	24.4	21.9	20.7	20.5	19.8	22.5	21.3	21.6	1.38
Mean weight	Red Sokoto	26.4	27.1	27.7	27.0	26.9	27.5	27.0	27.6	27.1	27.5	1.67
	Sahelian	21.4	22.9	24.9	22.9	23.1	24.1	22.9	23.5	23.2	23.5	1.88
Total protein	Red Sokoto	74.5	64.3	61.2	57.8	60.0	66.0	61.4	62.7	61.8	61.8	2.42
	Sahelian	70.2	56.1	63.1	65.1	67.2	67.1	64.5	65.9	68.7	68.6	3.98
Albumin	Red Sokoto	53.2	39.6	31.9	29.1	28.1	32.1	31.7	33.7	28.9	28.9	1.77
	Sahelian	50.8	35.5	34.1	33.4	35.6	33.5	32.3	32.8	34.5	34.5	2.91
Globulin	Red Sokoto	21.3	24.6	29.3	28.7	31.9	33.9	29.7	28.7	32.8	32.9	2.16
	Sahelian	19.5	20.6	28.9	31.7	31.7	33.7	32.3	33.1	34.2	34.1	3.56

Appendix 3. Analysis of variance data for birth weight of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	7.05444	2.3514	11.45	0.0005*
Error	14	2.87500	0.2053		
Total	17	9.92944			

Appendix 4. Analysis of variance data for weaning weight of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	10.66000	3.5533	2.18	0.1361
Error	14	22.84000	1.6314		
Total	17	33.50000			

Appendix 5. Analysis of variance data for weight change of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	7.9295	1.9824	1.23	0.3473
Error	14	21.0265	1.6174		
Total	17	28.9561			

Appendix 6. Analysis of variance data for average daily gain of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	5	136.260	27.2520	3.63	0.0179*
Error	19	142.6855	7.5097		
Total	24	278.9456			

Appendix 7. Analysis of variance data for Total dry matter intake of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	5	130649.7163	26129.9433	1.04	0.4723
Error	6	150853.0667	25142.1778		
Total	11	281502.7830			

Appendix 8. Analysis of variance data for total organic matter intake of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	5	114150.2047	22830.0409	1.05	0.4686
Error	6	130698.5834	21783.0972		
Total	11	244848.7881			

Appendix 9. Analysis of variance data for total crude protein intake of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	5	4043.3702	808.6741	1.48	0.3210
Error	6	3279.0321	546.5022		
Total	11	7322.3834			

Appendix 10. Analysis of variance data for apparent dry matter digestibility of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	84.0357	28.0119	0.93	0.4691
Error	8	240.7102	30.0887		
Total	11	324.7460			

Appendix 11. Analysis of variance data for organic matter digestibility of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	81.5988	27.1996	0.98	0.4488
Error	8	221.8852	27.7356		
Total	11	303.4841			

Appendix 12. Analysis of variance data for crude protein digestibility of Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	247.4435	82.4811	0.50	0.6919
Error	8	1316.6778	164.5847		
Total	11	1564.1213			

Appendix 13. Analysis of variance data for average daily gain of lactating Red Sokoto and Sahelian kids.

Source of variation	Df	SS	MS	F	Pr>F
Model	3	1132.145	377.382	0.36	0.779
Error	18	18657.7435	1036.5413		
Total	21	19789.889			

Appendix 14. Type 3 tests of fixed effects for repeated measures analysis of mean epg of growing Red Sokoto and Sahelian Kids infected with *H. contortus*.

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	22	23.98	<0.0001*
Breed	1	222	16.72	<0.0001*
Treatment*breed	2	22	10.75	<0.0001*
Period	9	192	4.74	<0.0001*
Treatment*period	18	192	1.92	0.0050*
Breed*period	9	192	0.93	0.5259
Treatment*breed* Period	18	173	1.04	0.4168

- Significant is apparent at the level shown on the table.

Appendix 15. Type 3 tests of fixed effects for repeated measures analysis of mean PCV concentration of growing Red Sokoto and Sahelian Kids infected with *H. contortus*

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	22	0.99	0.3876
Breed	1	22	0.31	0.5845
Treatment*breed	2	22	0.11	0.8963
Period	9	165	12.06	<0.0001*
Treatment*period	18	165	1.64	0.0560
Breed*period	9	165	0.79	0.6244
Treatment*breed*Period	18	165	0.80	0.6969

Significant is apparent at the level shown on the table

Appendix 16. Type 3 tests of fixed effects for repeated measures analysis of mean total protein concentration of growing Red Sokoto and Sahelian Kids infected with *H. contortus*.

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	21	0.90	0.4200
Breed	1	21	7.35	0.0131*
Treatment*breed	2	21	0.83	0.4493
Period	9	173	2.83	<0.0147*
Treatment*period	18	173	0.92	0.5554
Breed*period	9	173	0.41	0.9260
Treatment*breed* Period	18	173	0.63	0.8683

- Significant is apparent at the level shown on the table.

Appendix 17. Type 3 tests of fixed effects for repeated measures analysis of mean albumin concentration of growing Red Sokoto and Sahelian Kids infected with *H. contortus.*

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	21	1.43	0.2608
Breed	1	21	8.70	0.0077*
Treatment*breed	2	21	0.41	0.6720
Period	9	173	9.48	<0.0001*
Treatment*period	18	173	1.06	0.3971
Breed*period	9	173	1.59	0.1210
Treatment*breed* Period	18	173	1.04	0.4168

- Significant is apparent at the level shown on the table.

Appendix 18. Type 3 tests of fixed effects for repeated measures analysis of mean globulin concentration of growing Red Sokoto and Sahelian Kids infected with *H. contortus*

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	21	0.61	0.5508
Breed	1	21	2.13	0.1590
Treatment*breed	2	21	0.66	0.5275
Period	9	173	19.44	<0.0001*
Treatment*period	18	173	1.17	0.2935
Breed*period	9	173	1.36	0.2076
Treatment*breed* Period	18	173	1.01	0.4559

- Significant is apparent at the level shown on the table.

Appendix 19. Type 3 tests of fixed effects for repeated measures analysis of mean epg of lactating Red Sokoto and Sahelian Kids infected with *H. contortus*.

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	18	6.23	0.0088*
Breed	1	18	1.20	0.2879
Treatment*breed	1	18	1.21	0.2852
Period	12	261	4.74	0.1169

- Significant is apparent at the level shown on the table.

Appendix 20. Type 3 tests of fixed effects for repeated measures analysis of mean PCV concentration of growing Red Sokoto and Sahelian Kids infected with *H. contortus*.

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	22	0.99	0.3876
Breed	1	22	0.31	0.5845
Treatment*breed	2	22	0.11	0.8963
Period	9	165	12.06	<0.0001*
Treatment*period	18	165	1.64	0.0560
Breed*period	9	165	0.79	0.6244
Treatment*breed* Period	18	165	0.80	0.6969

Significant is apparent at the level shown on the table

Appendix 21. Type 3 tests of fixed effects for repeated measures analysis of mean total protein concentration of lactating Red Sokoto and Sahelian Kids infected with *H. contortus.*

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	151	0.53	0.5870
Breed	1	151	4.95	0.0276*
Treatment*breed	1	151	0.30	0.5448
Period	9	151	2.02	<0.0412*
Treatment*period	18	151	1.12	0.3414
Breed*period	9	151	1.22	0.2867
Treatment*breed* Period	9	151	0.55	0.8350

- Significant is apparent at the level shown on the table.

Appendix 22. Type 3 tests of fixed effects for repeated measures analysis of mean albumin concentration of lactating Red Sokoto and Sahelian Kids infected with *H. contortus*.

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	151	3.67	0.0279*
Breed	1	151	6.90	0.0095*
Treatment*breed	1	151	0.90	0.3446
Period	9	151	24.51	<0.0001*
Treatment*period	18	151	0.97	0.4951
Breed*period	9	151	1.19	0.3028
Treatment*breed* Period	9	151	1.02	0.4269

- Significant is apparent at the level shown on the table.

Appendix 23. Type 3 tests of fixed effects for repeated measures analysis of mean globulin concentration of lactating Red Sokoto and Sahelian Kids infected with *H. contortus*

Effect	Number df	Den df	F-value	Pr>F
Treatment	2	151	1.19	0.3068
Breed	1	151	0.18	0.6714
Treatment*breed	1	151	1.77	0.1856
Period	9	151	4.65	<0.0001*
Treatment*period	18	151	1.61	0.0627
Breed*period	9	151	0.35	0.9559
Treatment*breed* Period	18	151	0.84	0.5794

- Significant is apparent at the level shown on the table.

Appendix 24. Type 3 tests of fixed effects for repeated measures analysis of mean milk yield of lactating Red Sokoto and Sahelian Kids infected with *H. contortus*

Effect	Number df	Den df	F-value	Pr>F
Treatment	4	0	6.66	.
Breed	1	16	6.40	0.0223*
Treatment*breed	2	18	4.49	0.0263*
Period	18	376	3.00	<0.0001*
Treatment*period	18	151	1.61	0.0627
Breed*period	9	151	0.35	0.9559
Treatment*breed* Period	9	151	0.84	0.5794

- Significant is apparent at the level shown on the table.

Appendix 25

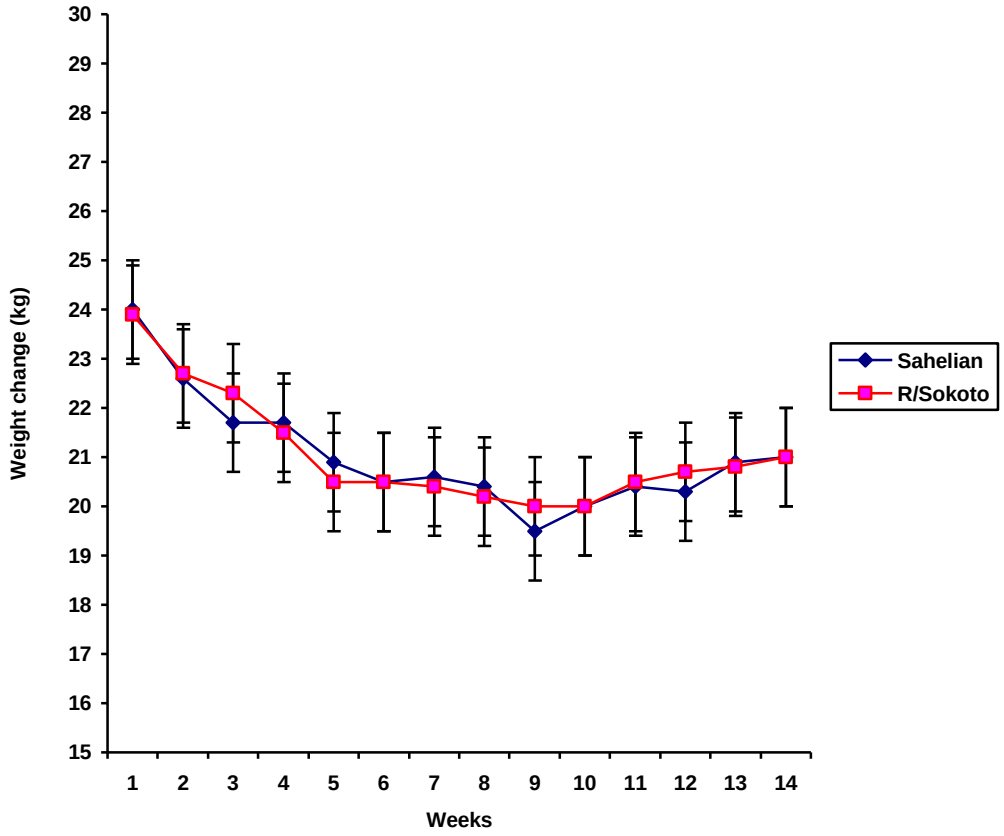

Fig 1: Weight changes of Dams of Sahelian and Red Sokoto goats

Appendix 26

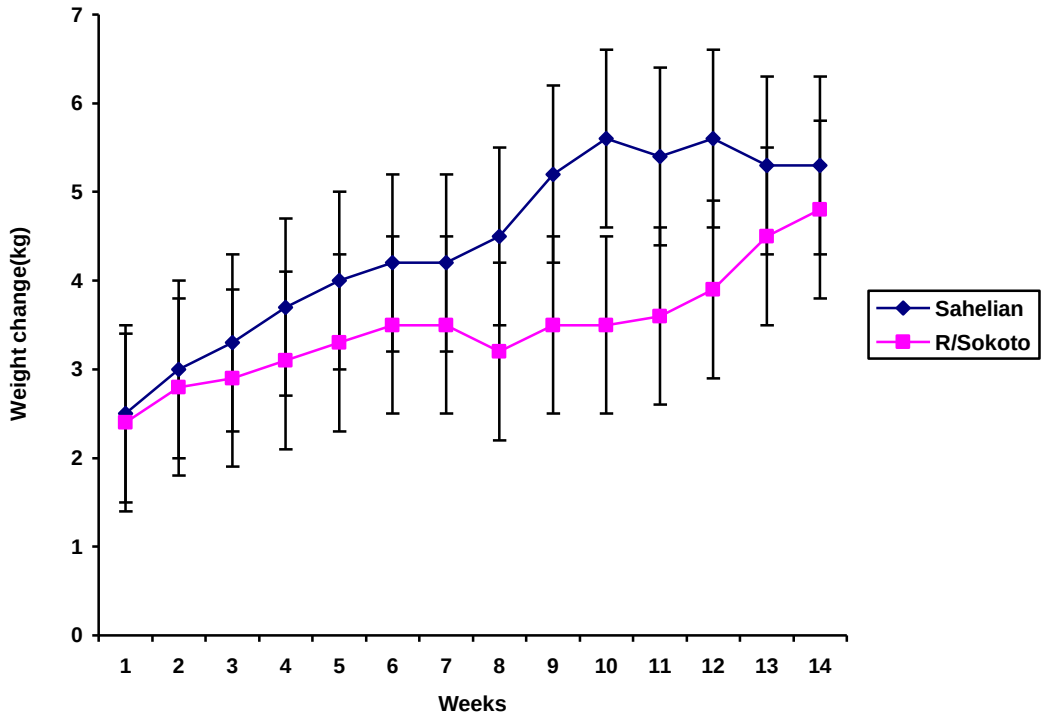

Fig 2: Pre-weaning weight change of Sahelian and Red Sokoto Kids

Appendix 27

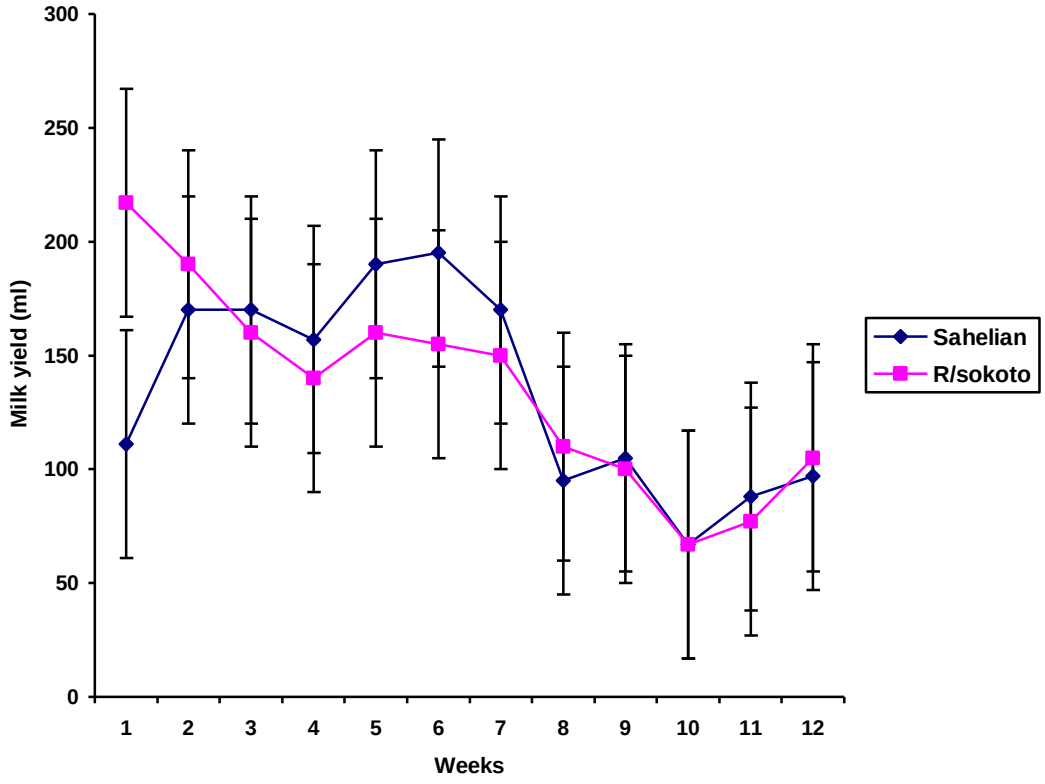

Fig 3: Milk yield of Sahelian and Red Sokoto goats

Appendix 28

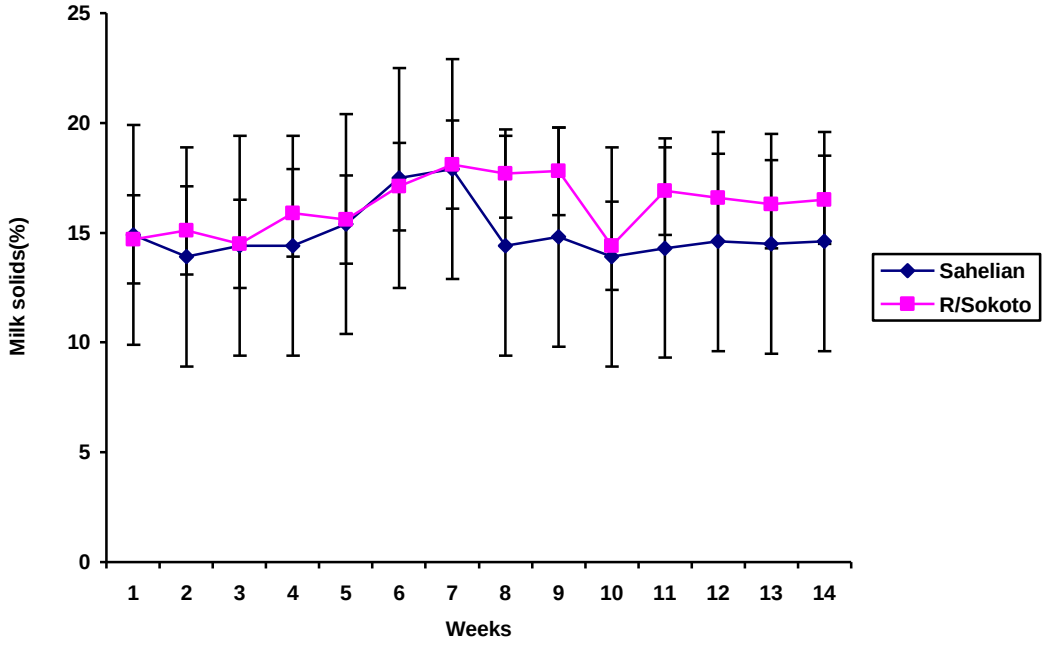

Fig 4: Total milk solids of Sahelian and Red Sokoto goats

Appendix 29

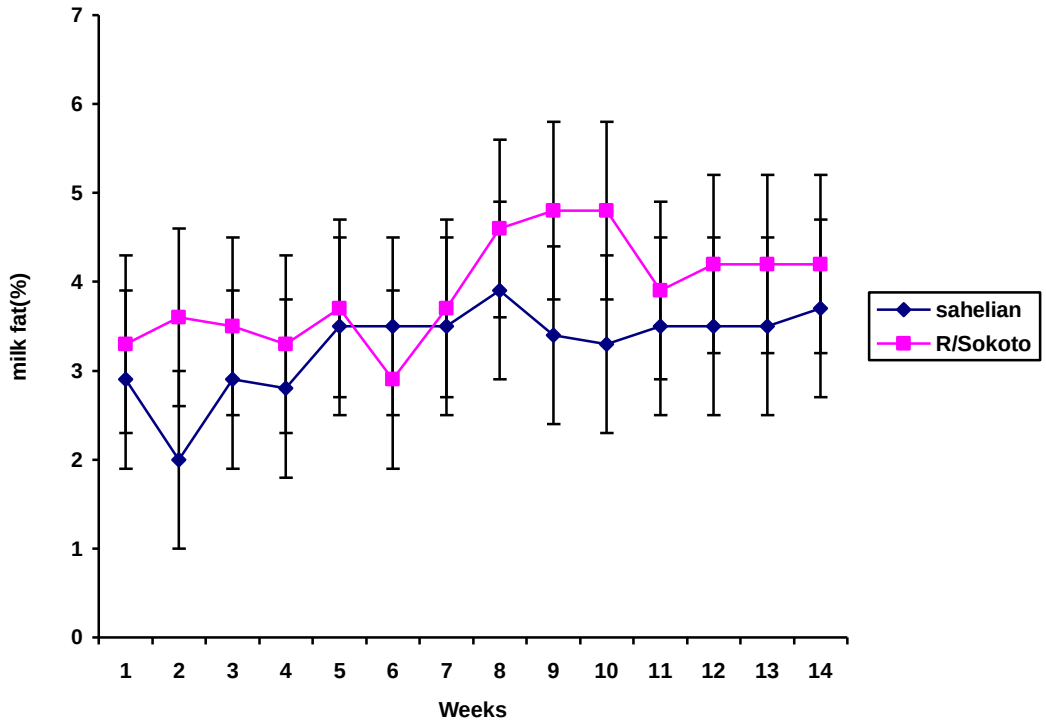

Fig 5: Milk fat concentration of the Sahelian and Red Sokoto goats

Appendix 30

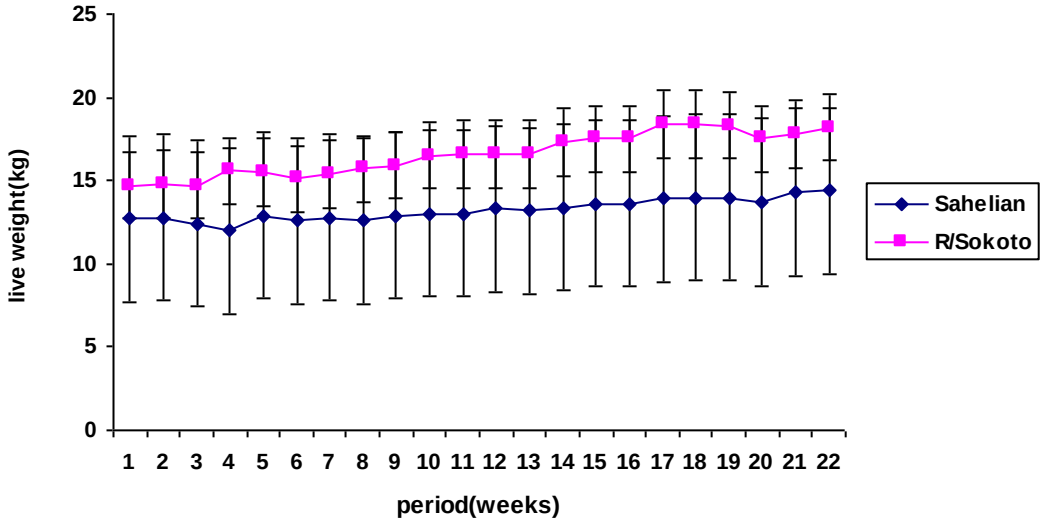

Fig 6: Post-weaning growth performance of Sahelian and Red Sokoto Kids

Appendix 31

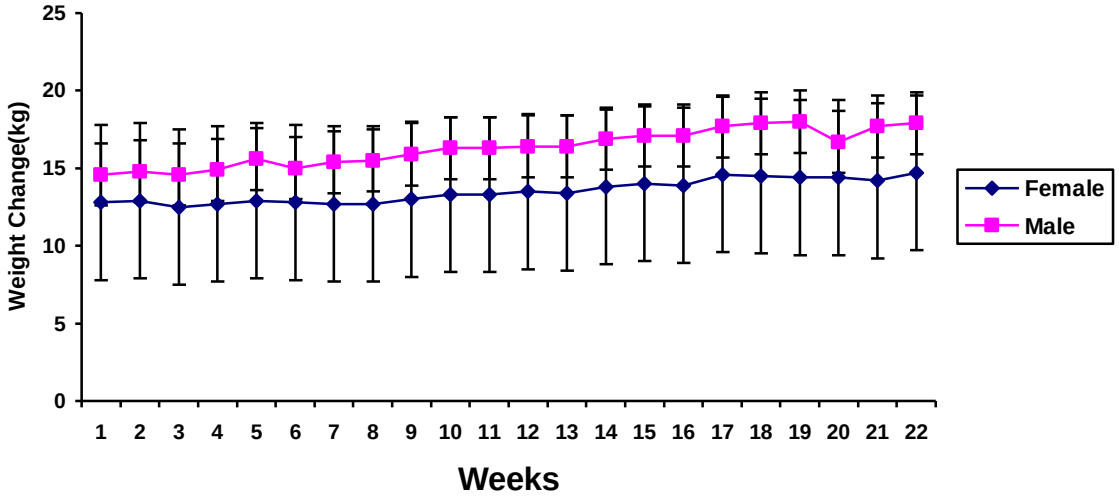

Fig 7:Post-weaning growth performance of Female and Male kids

Appendix 32

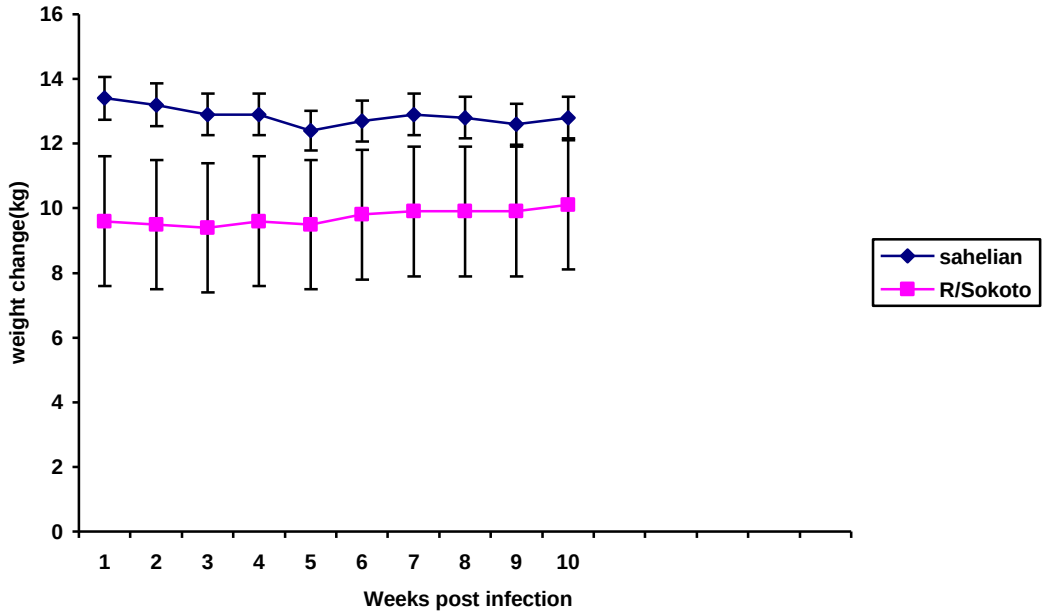

Fig 8: Effect of *H contortus* on weight change on sahelian and Red sokoto goats

Appendix 33

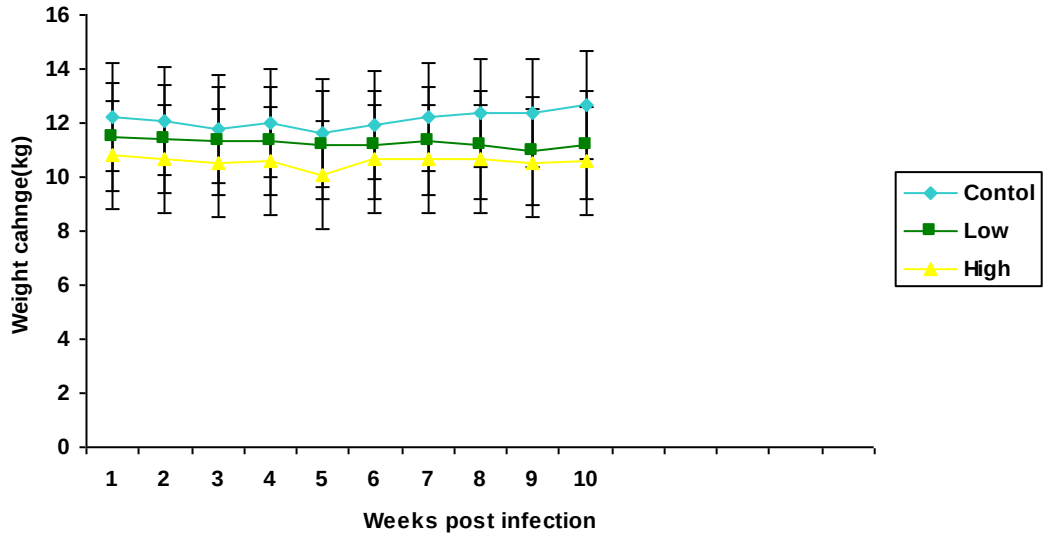

Fig 9: Effect of different levels of *H. contortus* infection on weight change of goats

Appendix 34

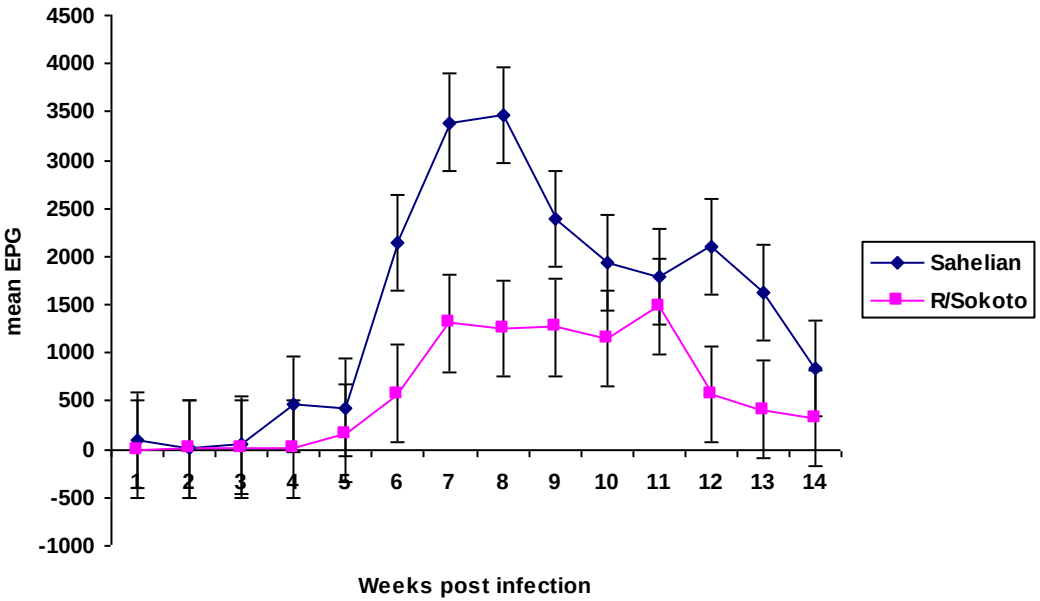

Fig 10: Egg per Gram (EPG) of Feaces recovered from infected animals.

Appendix 35

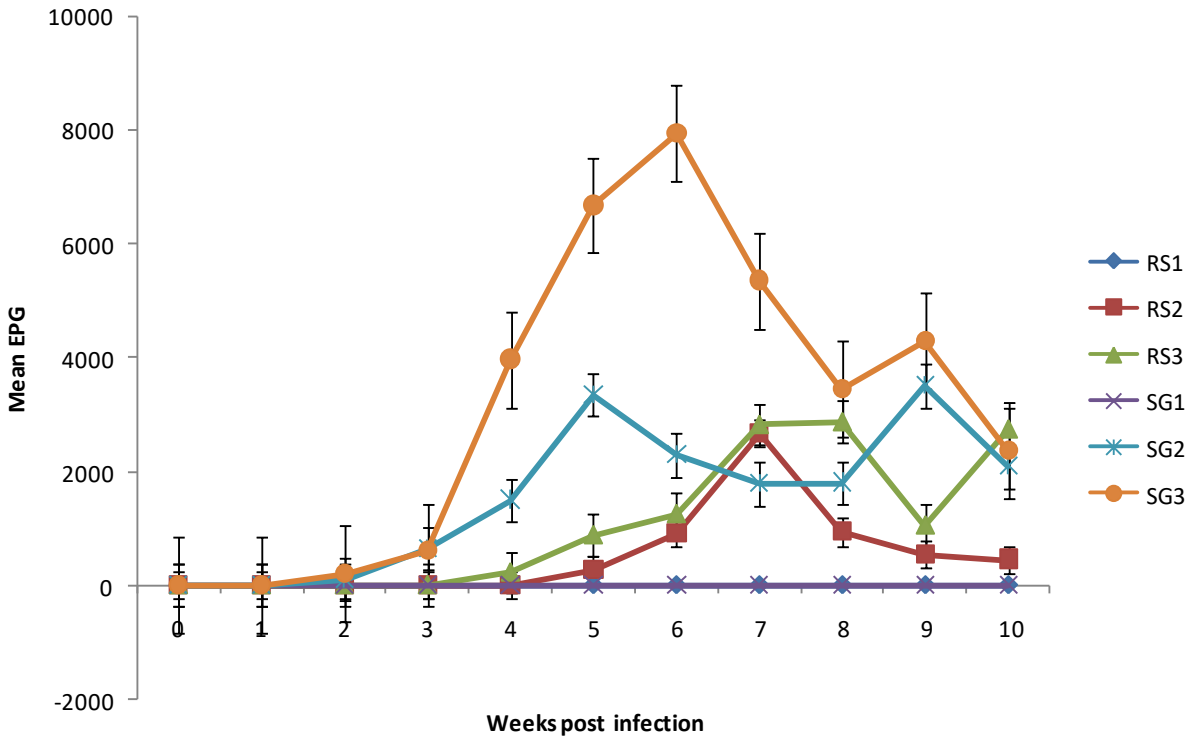

Fig 11: Egg per gram for different levels of *H. contortus* infection in Red Sokoto and Sahelian goats

KeyR1 = Control group of Red Sokoto goats S1= Control group of Sahelian goats

R2= Low infection group of Red Sokoto goats S2= Low infection group of Sahelian goats

R3= High infection group of Red Sokoto goats S3= High infection group of Sahelian goats

Appendix 36

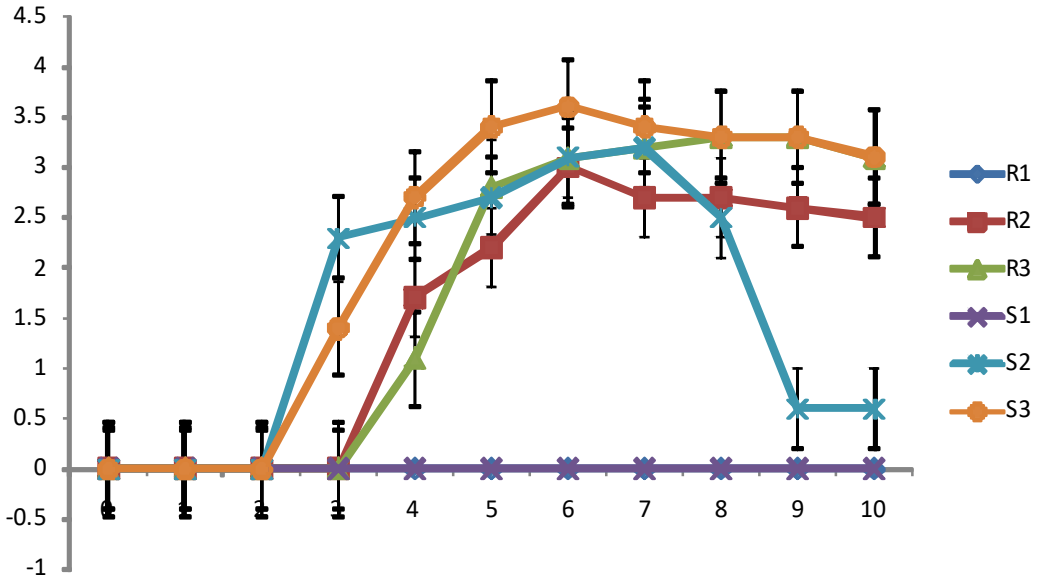

Fig 12. Transformed faecal egg count of growing Red Sokoto and Sahelian goats infected with H. contortus

Key

R1 = Control group of Red Sokoto goats

R2= Low infection group of Red Sokoto goats

R3= High infection group of Red Sokoto goats

S1= Control group of Sahelian goats

S2= Low infection group of Sahelian goats

S3= High infection group of Sahelian goats

Appendix 37

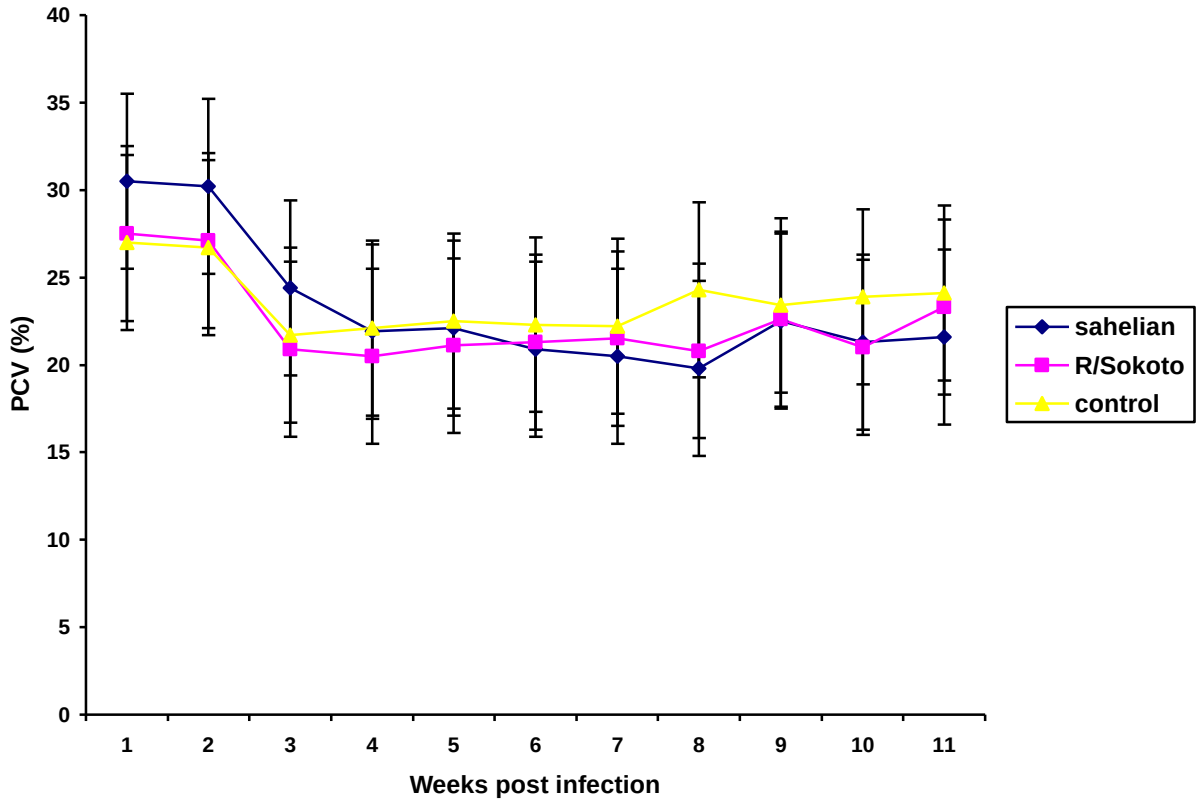

Fig 13: Effect of *H. contortus* on the PCV of Sahelian and Red Sokoto Goats

Appendix 38

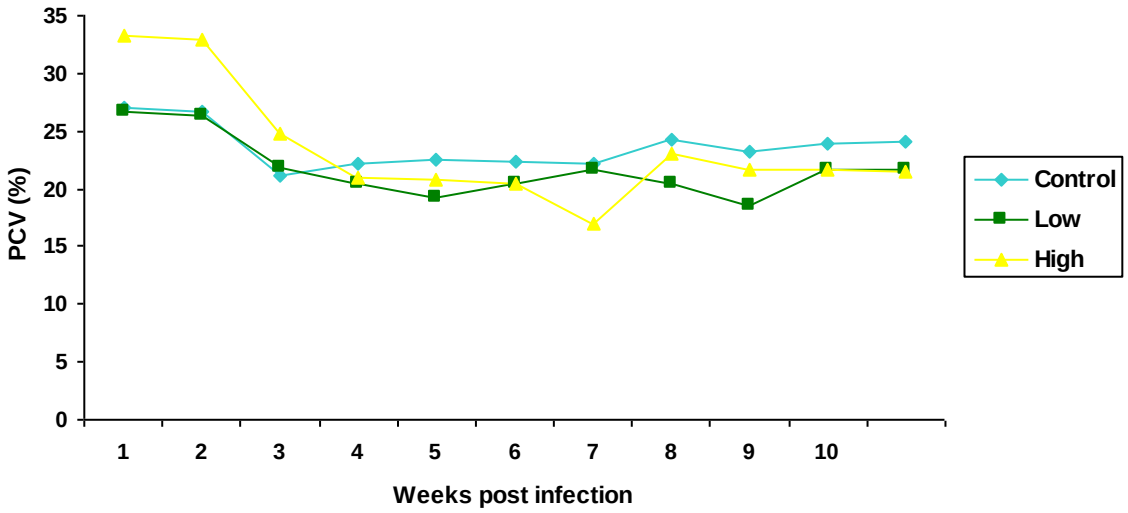

Fig 14 Effect of different levels of *H. contortus* infection on the PCV of experimental goats.

Appendix 39

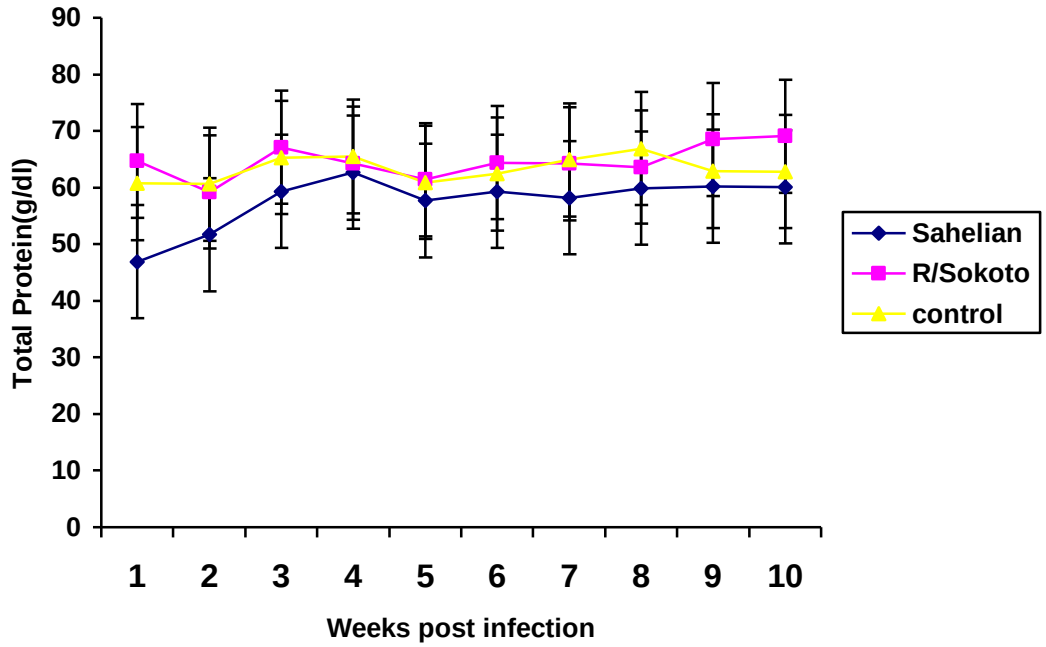

Fig 15: Effect of H contortus on total protein Sahelian and Red Sokoto goats

Appendix 40

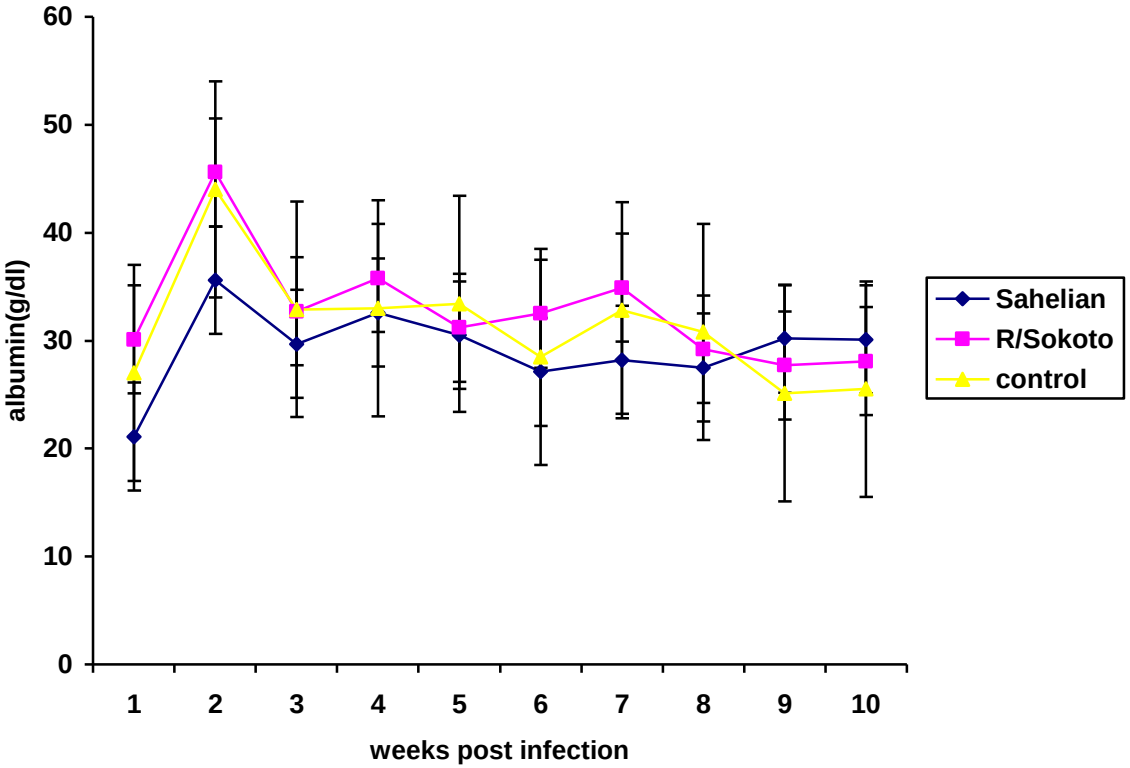

Fig 16: Effect of *H contortus* on Albumin of Sahelian and Red Sokoto goats

Appendix 41

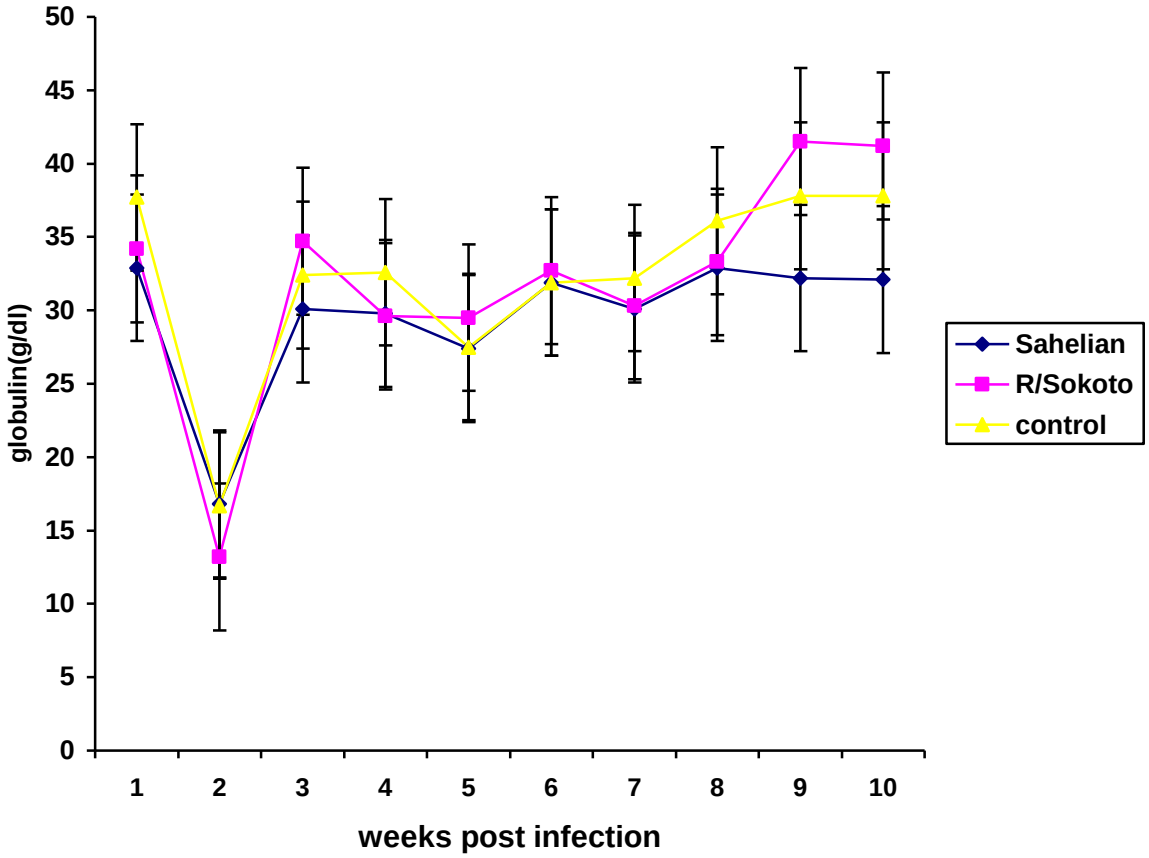

Fig 17: Effect of *H contortus* on globulin concentration of Sahelian and Red Sokoto goats

Appendix 42

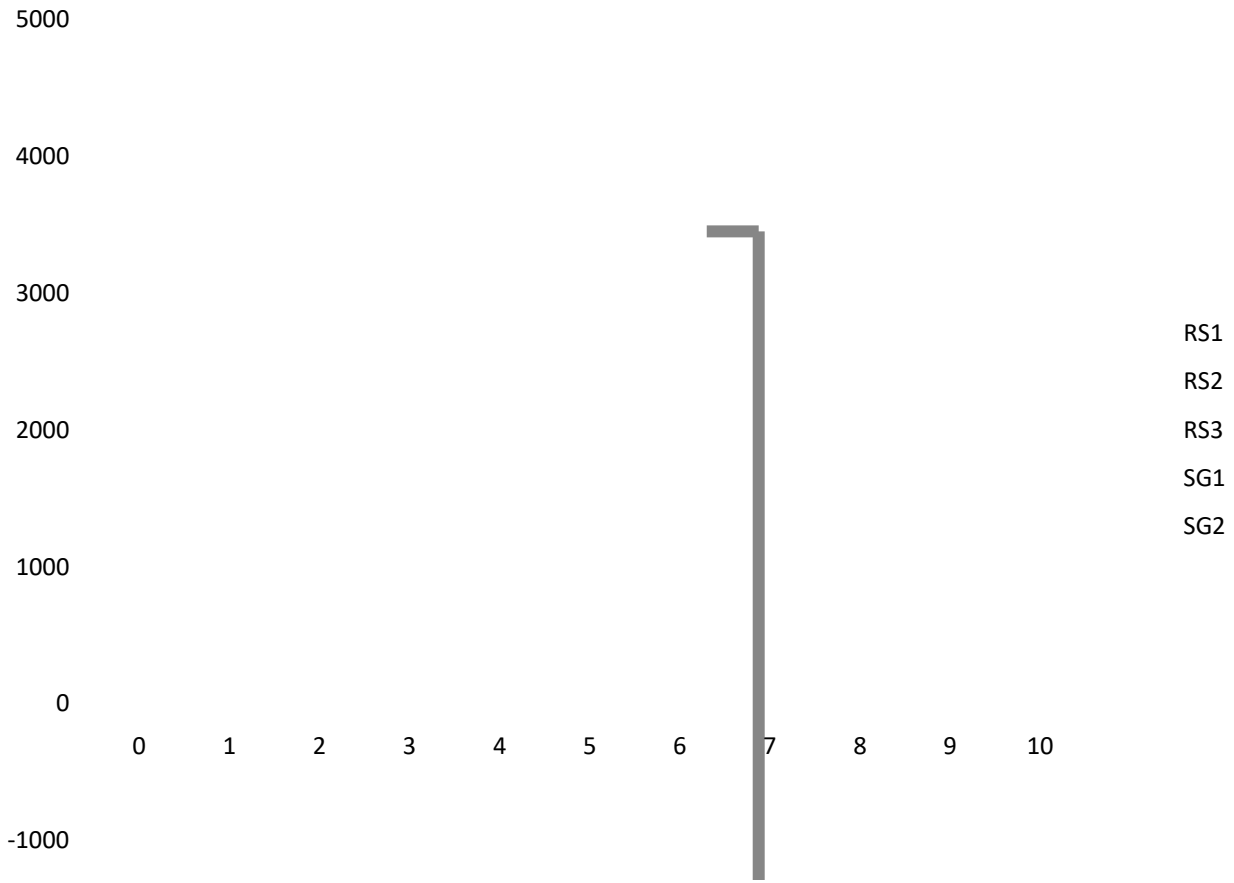

Fig 18: Feacal egg count (EPG) of lactating Red Sokoto and Sahelian goats infected with *H. contortus*

KeyR1 = Control group of Red Sokoto goats S1= Control group of Sahelian goats R2= Low infection group of Red Sokoto goats S2= Low infection group of Sahelian goats R3= High infection group of Red Sokoto goats

Appendix 43

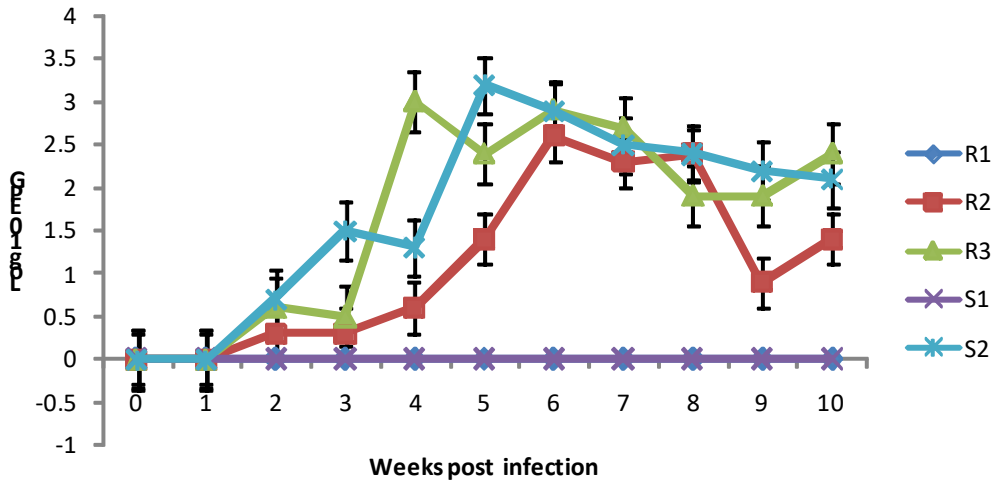

Fig 19 Transformed Feacal egg count (EPG) of lactating Red Sokoto and Sahelian goats infected with *H. contortus*

Key

R1 = Control group of Red Sokoto goats

R2= Low infection group of Red Sokoto goats

R3= High infection group of Red Sokoto goats

S1= Control group of Sahelian goats

S2= Low infection group of Sahelian goats

Appendix 44

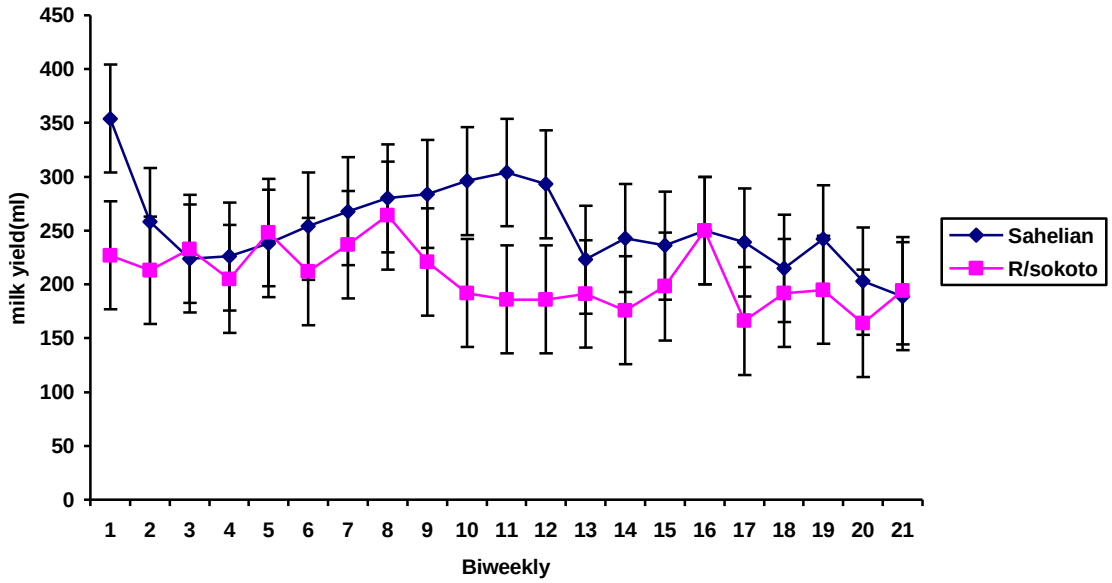

Fig 20: Effect of *H. contortus* ($75L_3$ and $100L_3$) on milk yield of Sahelian and Red Sokoto goats

Appendix 45

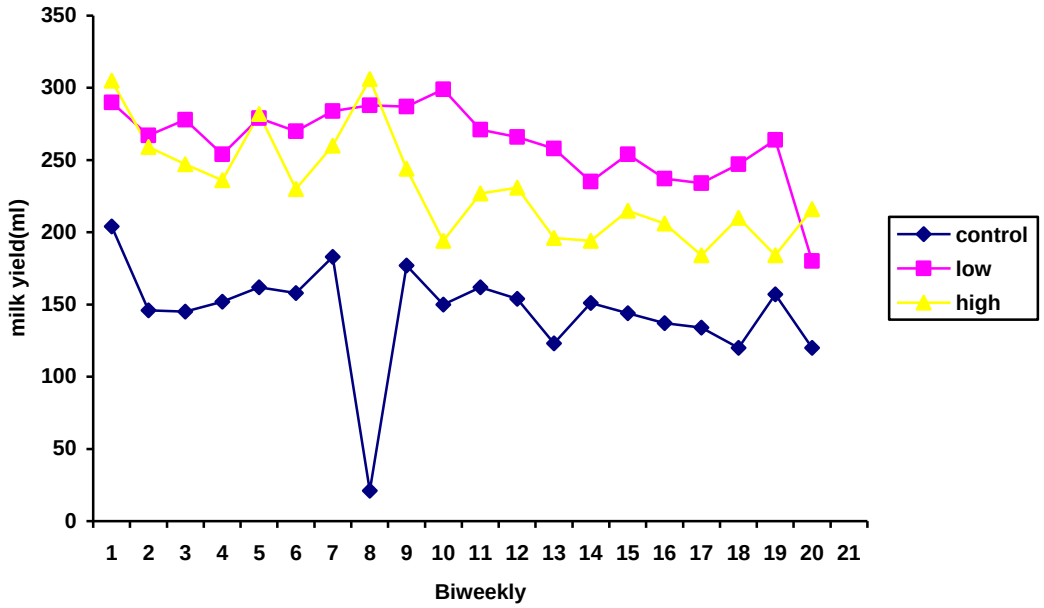

Fig 21: Milk yield in Red Sokoto and Sahelian does experimentally infected with *H. contortus* at $75L_3$ and $100L_3$.

Appendix 46

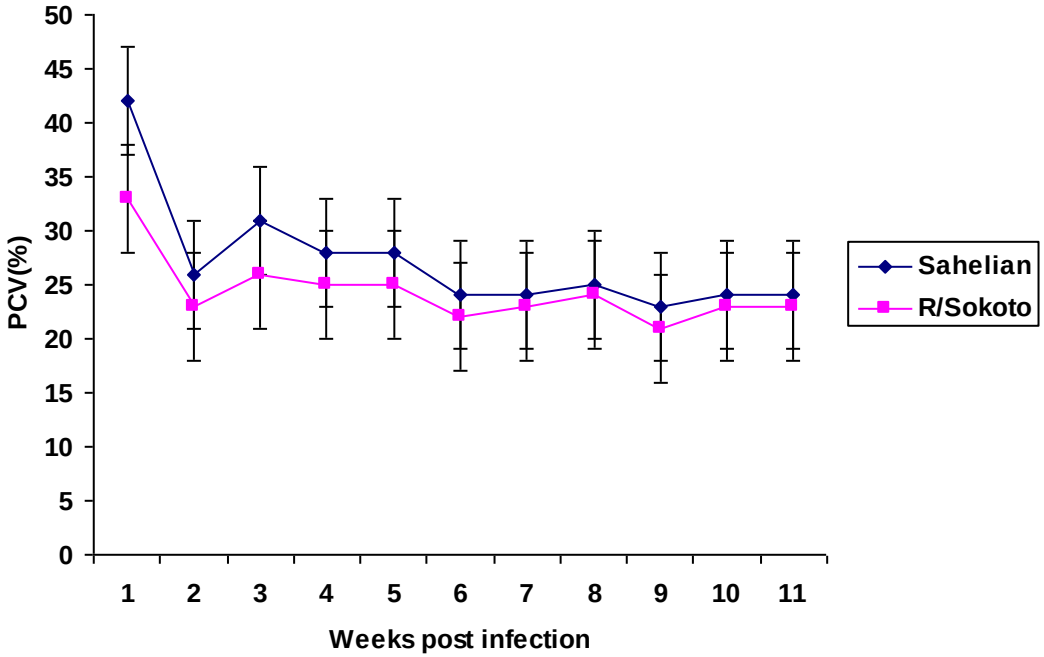

Fig 22: PCV values of Red Sokoto and Sahelian does infected with L3 of *H. contortus* at $75L_3$ and $100L_3$/kg.

Appendix 47

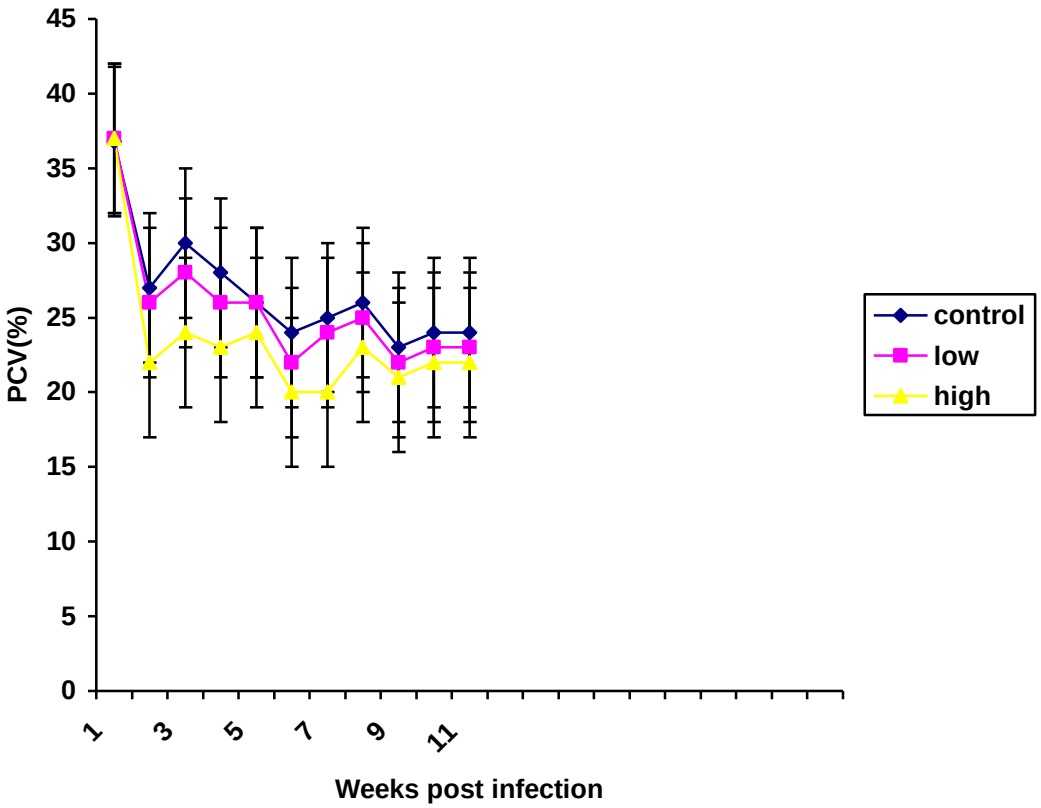

Fig 23: PCV values of Red Sokoto and Sahelian doaes infected with different levels of *H. contortus* at $75L_3$ and $100L_3$/kg.