A STUDY ON THE RELATIONSHIP BETWEEN FAMACHA© SCORES AND PACKED CELL VOLUME, FECAL EGG COUNTS AND ADULT *HAEMONCHUS* COUNTS IN RED SOKOTO GOATS AT SLAUGHTER IN ZARIA, NIGERIA.

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DEPARTMENT OF VETERINARY PARASITOLOGY AND ENTOMOLOGY
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

DECEMBER, 2014

DECLARATION

I declare that the work in this thesis entitled, "**A study on the relationship between FAMACHA© scores, Packed Cell Volume, Fecal Egg Counts and adult *Haemonchus* counts in Red Sokoto goats at slaughter in Zaria, Nigeria**", has been carried out by me in the Department of Veterinary Parasitology and Entomology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria. The information derived from literatures has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Yusuf Malum HEZEKIAH **……**
……

Signature **Date**

CERTIFICATION

This thesis entitled "A STUDY ON THE RELATIONSHIP BETWEEN FAMACHA© SCORES, PACKED CELL VOLUME, FECAL EGG COUNTS AND ADULT *HAEMONCHUS* COUNTS IN RED SOKOTO GOATS AT SLAUGHTER IN ZARIA, NIGERIA" by Yusuf Malum HEZEKIAH meets the regulation governing the award of Master of Science Degree Veterinary Parasitology of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this thesis to my beloved daughter **Jochebed Nde'izina Azumi Yusuf,** who was conceived and born in the course of my Masters' programme. May the good Lord keep and bless her with long life and enable her contribute to the development of knowledge and betterment of the society.

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ABBREVIATIONS

A: G	-	Albumin: globulin ratio
BCS	-	Body condition score
CBN	-	Central Bank of Nigeria
EDTA	-	Ethylene diamine tetra acetate
EPG	-	Egg per gram
FAMACHA	-	Faffa Malan chart
FEC	-	Fecal egg count
FS	-	FAMACHA score
GI	-	Gastrointestinal
GIT	-	Gastrointestinal tract
L_1	-	First larval stage
L_2	-	Second larval stage
L_3	-	Third larval stage
L_4	-	Fourth larval stage
L_5	-	Fifth larval stage
MCV	-	Mean corpuscular volume
NEFA	-	Non esterified fatty acid
PCV	-	Packed cell volume
TP	-	Total protein
VTH	-	Veterinary Teaching Hospital
WC	-	Worm count
β	-	Beta
βHB	-	Beta hydroxybutyrate

ABSTRACT

The FAMACHA© system was developed to assist farmers in identifying small ruminants clinically infected by haemonchosis and therefore in need of treatment with anthelmintics, against the blanket treatment of all animals irrespective of their worm burdens, resulting in anthelmintic resistance. This study was aimed at carrying out a preliminary evaluation of the sensitivity and specificity of the FAMACHA©. The colour of the ocular conjunctivae of 300 goats presented for slaughter was scored on a 1-5 scale using the FAMACHA© card and blood samples were collected from each animal for determination of Packed Cell Volume (PCV) and biochemical analyses. Fecal sample and abomasum were collected from each animal for determination of fecal egg counts (FEC) and the abomasum worm (adult *Haemonchus*) counts respectively. The accuracy of the chart was evaluated by using PCV as the gold standard for anemia, that is PCV≤ 18%.The mean PCV for animals with FAMACHA© scores (FS) 1,2,3,4, and 5 were 32.1±0.42, 31.3±0.36, 28.3±0.43, 23.8±0.66 and 18.1±1.69 respectively. Correlation between FS and PCV was negative (r = -0.6184) and highly significant (P<0.0001). The mean adult worm counts for animals with FS of 1, 2, 3, 4, and 5 were 9.76±5.56, 41.50±7.76, 119.89±14.16, 332.54±61.67 and 833.90±412.67 respectively. There was a highly significant (P<0.0001) positive correlation between FS and adult worm count (r = 0.3216). The mean FEC for animals with FS 1, 2, 3, 4, and 5 were 269.47±110.37, 926.49±228.30, 1757.57±240.65, 2488.50±394.04 and 5923.26±2387.50 respectively. The correlation between FS and FEC was positive (r=0.3191) and highly significant (P<0.0001). The mean FEC for goats with PCV ranges of 7-29, 15-39, 12-39, 24-38 and 25-38 were 5923.26±2387.50, 2488.50±394.04, 1757±240.65, 926.49±228.30 and 269.47±110.37 respectively. The mean Body Condition scores (BCS) for goats with FS of 1, 2, 3, 4, and 5 were 4.87±0.064,

4.23±0.057, 3.43±0.064, 2.28±0.11 and 1.70±0.127. There was a negative correlation between BC and FS (r = - 0.9937) and this was highly significant (P<0.0001).When animals with FS 4 & 5 were considered anemic, sensitivity of the FAMACHA© system was found to be 84.2% while specificity was 79.7%. Sensitivity increased to 100% but specificity decreased to 42.6% when animals with FS 3, 4, and 5 were considered anemic. Serum levels for total protein, albumin, urea and cholesterol were all within the normal range for the breed. It was therefore concluded that the FAMACHA© system could serve as a useful on - the - farm tool for the diagnosis of clinical haemonchosis in the red Sokoto goat, and give a guide on goats that need to be treated with an anthelmintic.

TABLE OF CONTENTS

Page

Title Page……...ii

Declaration……iii

Certification……iv

Dedication……v

Acknowledgements...……vi

Abbreviations……...vii

Abstract……viii

Table of Content……...x

List of Tables……....xiv

List of Plates…...……...xv

List of Appendices……xvi

1.0 CHAPTER 1: INTRODUCTION……..……..1

1.1 Importance of Goats in the Society ……1

1.2 Statement of the Research Problem……5

1.3 Justification of the Study……...……6

1.4 Aim of the Study……..…….…..7

1.5 Objectives of the Study…..…….……....7

1.6 Research Hypothesis……..…..7

1.7 Scope and Limitation of the Study……..……....8

2.0 CHAPTER 2: LITERATURE REVIEW…….……..9

2.1 Etiology of Haemonchosis…….9

2.2 Classification and Biology of *Haemonchus contortus*…..……....9

2.3 The Life-cycle of *Haemonchus contortus*……...11

2.4 Clinical Pathology……...…….....13

2.4.1 Gross lesions……...13

2.4.2 Histopathologic lesions……...14

2.5 Clinical Signs and Diagnosis……14

2.6 Immunity against Parasites…….....15

2.6.1
Premunition……..….15

2.6.2 The self-cure phenomenon……..16

2.6.3 The practical significance of self-cure……18

2.7 The anemia in Helminthosis……..……...19

2.7.1 Normocytic anemia…….....…….…..19

2.7.2 Microcytic and Macrocytic anemia……..……...20

2.7.3 The anemia due to haemonchosis..…..…….. 20

2.8 Resistance to Anthelmintics by Helminth Parasites…….….21

2.8.1 Definition of drug resistance……...21

2.8.2 Factors responsible for anthelmintic resistance……...……21

2.8.3 Early reports of anthelmintic resistance……....22

2.8.4 Anthelmintic resistance around the world……..……..22

2.8.5 Diagnosis of anthelmintic resistance……..22

2.9 Selective Treatment and the Use of FAMACHA©……....23

2.9.1 Selective Treatment……23

2.9.2 The FAMACHA© system……24

2.10 Advantages and Disadvantages of the FAMACHA© System……..26

2.11 Measures of Assessing the Nutritional and Health Status of Goats……26

2.11.1 Body Weights and Condition Scoring……26

2.11.2 Fecal Egg Counts……...……..……27

2.11.3 Packed Cell Volume…….…29

2.11.4 Detection of Anemia……..……...30

2.12 Determination of Health and Nutritional Status of goats using blood metabolites…… 31

2.12.1 Blood Chemical Constituents related to Carbohydrate and Lipid metabolism..31

2.12.2 Blood Chemical Constituents related to Protein Metabolism…….……33

3.0 CHAPTER 3: MATERIALS AND METHOD…….35

3.1 Study Area……..…35

3.2 Determination of Sample Size……..35

3.3 Sample Collection…….……..36

3.4 Scoring Procedure……..…..…36

3.4.1 Body Condition Scoring…….36

3.4.2 FAMACHA© Scoring ……..……...38

3.4.3 Blood Sample Analyses……..38

3.4.3.1 PCV Determination……..38

3.4.3.2 Biochemical Analyses……..39

3.4.3.3 Screening for haemoparasites……..39

3.5 Fecal Sample Analyses……..….39

3.5.1 Processing of abomasum…….……40

3.6 Data Analysis……41

4.0 CHAPTER 4: RESULTS…..……..….42

4.1 Body Condition Scores…….….45

4.2 Relationship between FAMACHA© Scores and PCV……...…..……...44

4.3 FAMACHA© Scores, PCV and Anemia Thresholds……..47

4.4 Relationship between Fecal Egg Counts and FAMACHA© Scores…….…….49

4.5 Relationship between Adult *Haemonchus* Counts and FAMACHA Scores…51

4.6 Distribution of Worm Burdens in the Sampled Goats……..…51

4.7 Monthly distribution of Fecal Egg and Adult *Haemonchus* Counts in the Sampled Goats…….....53

4.8 Haemoparasites…….....57

4.9 Ectoparasites……57

4.10 Blood Metabolites…….….57

5.0 CHAPTER 5: DISCUSSION……..……....61

6.0 CHAPTER 6: CONCLUSION AND RECOMMENDATION……..66

6.1 Conclusion……..…….66

6.2 Recommendation……..……..66

REFERENCES…….67

APPENDICES…….81

LIST OF TABLES

Table 3.1: Body condition score descriptions used in the assessment of the goats...37

Table 4.1: Relationship between Body Condition and FAMACHA© Scores of the Goats …….43

Table 4.2: Relationship between FS and PCV of the goats……45

Table 4.3: Mean ± SEM of PCV, FEC, BCS and Adult Worm counts of RS with corresponding FAMACHA Scores……..46

Table 4.4: Showing the frequencies of false positives & negatives, true positives & negatives, FS and PCV values at different anemia thresholds…….…..48

Table 4.5: Relationship between FS and FEC of the goats……..50

Table 4.6: Relationship between FS and adult *Haemonchus* counts of the goats…..52

Table 4.7: *Haemonchus* and FEC monthly dynamics in the two slaughter slabs……54

Table 4.8: Relationship between Grouped FS, different PCV ranges and some parameters in the goats……56

Table 4.9: Relationship between different FS and Mean ±SEM of some blood metabolites in the goats……..…58

Table 4.10: Relationship between grouped PCV, FS and some blood metabolites in the goats…….60

LIST OF PLATES

Plate I: Photo plate showing the dorsal lancet in the buccal cavity at the anterior part of *Haemonchus contortus*……10

Plate II: Photo plate showing the spicules and dorsal rays in the male bursa of *Haemonchus contortus*……11

Plate III: Photo plate showing the FAMACHA© anemia chart…….25

LIST OF APPENDICES

Appendix I: Working formula for the determination of sensitivity and specificity of the FAMACHA© system……81

Appendix II: Working formula for the determination of Egg per gram (EPG) of fecal samples……82

CHAPTER ONE

INTRODUCTION

1.1 Importance of Goats in the Society

Nigeria has about 56.599 million small ruminants made up of 22.104 million sheep and 34.495 million goats (Bourn *et al*., 1994).Goats are important to the subsistence, economic and social livelihoods of many resource-poor farmers in developing countries (Kosgey, 2004). They produce about 17 and 12% of tropical Africa's meat and milk, respectively (Lebbie, 2004), which are likely to be underestimates, since most of the utilization of goats goes unrecorded. Communal goats fulfill multiple roles that include provision of meat, manure, milk and cash from sales of the goats and their by-products (Thornton *et al*., 2002). Goats also play a major role in traditional ceremonies (Ayalew *et al*., 2001).Goats in communal areas are less susceptible to droughts than cattle and have lower feed and capital requirements than larger ruminants (Iniguez, 2004). They are better able to utilize a variety of feedstuffs, including fibrous crop residues (Holst, 1999).

In addition, goats have shorter generation intervals, reaching puberty at five to nine months of age (Saico and Abul, 2007) and have a higher prolificacy in comparison with the larger ruminants. Goats are renowned for controlling bush encroachment (Mahanjana and Cronje, 2000).Despite their value to society, goat research and development has been neglected relative to sheep (Devendera, 2002; Lebbie, 2004).

Goat production is mainly in the hands of subsistence farmers who keep them for their meat and socio-economic reasons. These animals are either herded all year round, left on free range

throughout the year or during the non-cropping season, or tethering throughout the year or during the cropping season. However, due to limitation on grazing land and financial resources, majority of farmers keep only small numbers ranging from one to ten, and are mostly raised intensively or semi-intensively and fed grains, concentrates, food left-overs, et cetera (Ndamukong *et al*., 1987).

In Nigeria, the Red Sokoto (RS) goat is the most widespread and well known breed constituting about 70% of the total goat population in the country (RIM, 1992). However, the production of these animals is limited by livestock diseases. Notably, diseases caused by endo-and ecto-parasites are a major setback to profitable animal production in Nigeria (SchilhornVanVeen, 1973).

The impact of diseases and parasites may be through high morbidity, mortalities, abortions, or subclinical effects manifested as weight loss or reduced gains. The negative impact of diseases and parasites may also be through the financial implications involved in controlling or overcoming the effects of disease and mortality (Mahusson *et al*., 2004; Sissay *et al.*, 2006). Diseases and parasites have a heavy impact on kids because of the poor immunity status of these young animals leading to an increased susceptibility (Sebei *et al.*, 2004). High kid mortality diminishes the benefits of the high reproductive performance of does. Pre-weaning mortality of up to 30% has been recorded with kids in Malawi (Ficarelli, 1995). Diseases also cause abortions and stillbirths (Aitken, 2007).

Incidences of diarrhea are high at the beginning of the rainy season, especially in kids. The problem of parasitism is compounded by the fact that, under the communal system, livestock are usually reared extensively (Bayer *et al*., 2001). This increases infestation and makes control measures difficult to implement. Helminthes are associated with production losses and have profound depressive impacts upon long-term animal productivity. Helminth infestations

contribute immensely to anemia (Vatta *et al*., 2001; van Wyk *et al.*, 2006). Parasites also reduce voluntary feed intake, efficiency of feed utilization and increase the endogenous loss of protein in the gastrointestinal tract (Alexander and Mandonnet, 2005).

Although several species of gastrointestinal nematodes co-infect these animals, the abomasal nematode *Haemonchus contortus* is particularly important and causes severe anemia and death in heavy infections and substantial production losses even at low infection levels (Allonby and Urquhart, 1975; Nwosu *et al*., 1996; Fakae *et al*., 1999).

Anthelmintics remain the principal means of control of gastrointestinal parasites. Over time with regular and frequent use of anthelmintics, multiple anthelmintic resistance in *H.contortus* and other helminthes is becoming a severe problem in the livestock industry (Kaplan *et al*., 2004; Jan and Gareth, 2002). In Africa, anthelmintic resistance has been reported in both the commercial and resource - poor farming sectors in at least 13 countries including Nigeria (Mbuh *et al.,* 2008; Fashanu and Fagbemi, 2003). Resistance has developed because the typical strategy used by small ruminant producers for controlling gastrointestinal nematodes, especially *H. contortus,* involves the treatment of all animals at fixed frequent intervals during peak transmission periods and or treating the entire group when one or more animals demonstrate clinical signs suggestive of worm infection (Kaplan *et al*., 2004). Although this and other strategies may seem effective in controlling nematode parasites, they also place heavy genetic selection pressure for resistance on nematode populations. This is because all worms in all animals are exposed to the drug, and unexposed environmental refugia are therefore kept at a low level. Refugia are the proportion of a population of worms that are sensitive to a dewormer or in refuge from a dewormer (Luis, 2006). When treating all animals in a herd as is commonly practiced, only resistant worms survive, which subsequently contaminate clean pastures. However, if only animals in need are treated and they go back to contaminated pasture, the resistant worms can breed with sensitive worms and maintain a worm population

that should still respond to anthelmintics (Luis, 2006). Hence, current recommendations include treatment of only animals in need (selective treatment). Untreated animals will harbor sensitive worms.

The major limitation to instituting a selective treatment approach has been the lack of an efficient and practicable means of identifying those animals requiring treatment. This problem has been solved by a system developed for identifying sheep that are anemic. The FAMACHA© system was developed in South Africa (Malan *et al*., 2001; Bath *et al*., 2001). The conjunctiva of individual sheep and goat is matched to a simple color chart to grade anemia (a diagnostic feature of haemonchosis) to identify the worst affected animals for treatment. The chart has five color categories (scores), each corresponding to a particular degree of anemia. Score 1 represents a healthy animal (normal reddish eye conjunctivae), while score 5 represents a highly anemic animal (porcelain white conjunctivae). Trials on commercial sheep in South Africa and the United States have demonstrated the practical usefulness of the chart for aiding in the control of *H. contortus* in small ruminants (Bath *et al*., 2001; Kaplan *et al*., 2004). However, only limited research has been carried out to evaluate the applicability of the FAMACHA©chart in goats under resource - poor conditions (Vatta *et al*., 2001) where nutritional deficiencies, and hemoparasitism may play important roles as causes of anemia. It is usually considered that the response of goats to nematode infection is less efficient than that of sheep (Hoste *et al*., 2005).This is attributed mainly to their browsing behavior, which limits contact with nematode L3 (infective third larval stage) in the environment, especially at soil level, which is believed to have contributed to the evolution of less effective immunoregulatory mechanisms in goats than in sheep. This makes it difficult to extrapolate results from sheep to goats. Moreover, because most published studies on the usefulness of the FAMACHA© system have been performed in South Africa and the United States, it is important that the method be tested in other areas of the world before its use can be broadly recommended.

1.2 Statement of the Research Problem

Haemonchosis is a highly devastating parasitosis of small ruminants wherever they are found. It is characterized by severe anemia and anarsaca (Susan, 2009).

Great economic losses occur in goats reared in Kano and Zaria areas due to haemonchosis, especially during the rainy season. This has been estimated to be up to sixty-million naira (N60m) annually, equivalent to one-hundred and nine million ($109m) US dollars (Akerejola *et al*., 1979; CBN, 2006).

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

Most experimental studies on the FAMACHA© system have been conducted in sheep. There is every need to evaluate its usefulness in the Red Sokoto goat, being a highly prolific breed and accounting for about 70% of the total population of goats in Nigeria (RIM, 1992). This method was tested in goats farmed under resource-poor conditions in South Africa (Jan and Gareth, 2002), and a test sensitivity of 76 to 85% was obtained, meaning that the system could be used to identify correctly 76-85% of those animals in need of treatment with an anthelmintic. However, the researchers recommended the need for further work in goat populations in other parts of the world.

1.3 Justification of the Study

There is still difficulty in the accurate diagnosis of haemonchosis as a specific disease entity both by veterinarians, veterinary assistants and farmers. By the time typical clinical signs such as “bottle jaw”, emaciation and weakness are noticed, the disease would have reached an

advanced stage with poor prognosis. Hence, the need for a simplified and accurate system for the diagnosis of the disease entity in goat populations in Nigeria. In addition, other factors such as nutrition, ectoparasitic infections, and extant diseases may influence the anemic state of the animal. It has been recommended (Spicket, 2009) that the FAMACHA© system be supported by other criteria such as clinical signs and body condition score. This study will take them into consideration in the evaluation of the FAMACHA© system, as research has shown that there is an interaction between nutrition and nematode parasitism (Hoste *et al*.,2005) as well as changes in some blood metabolite levels. It is, therefore, important to determine the relationships, if any, between blood metabolite levels and parameters that indicate clinical haemonchosis. Little, if any information is available on relationships of concentrations of nutritionally -related blood metabolites with fecal egg counts, FAMACHA© scores, and Packed Cell Volume in RS goats.

The use of the FAMACHA© system would assist in the production of meat animals with minimal chemical (anthelmintic) input, thus reducing chemical residues in meat.

The system would also help in identifying those animals that are genetically resistant to *H.contortus* (those with frequently low FAMACHA© scores) which can be bred with susceptible ones in order to increase the herd resistance. Highly susceptible animals (those with frequently high FAMACHA© scores) can be identified and culled.

Adequate control of haemonchosis will help in improving the production of goats in Nigeria and hence, increase the source of the much needed animal protein at a cheaper rate for the ever increasing population. This is even most desirable now as more people are discouraged or restricted from beef in preference to mutton and goat meat due to health challenges.

1.4 Aim of the Study

The primary aim of this study is to evaluate the FAMACHA© chart system in relation to PCV, FEC and adult worm counts so as to ascertain its accuracy as a tool for detection of clinical anemia due *H. contortus* in RS goats.

1.5 Objectives of the Study

1. To score goats using the FAMACHA© chart and relate the score with PCV, FEC and adult *H. contortus* counts in the goats.
2. To test the reliability of the FAMACHA© scoring in identifying anemic goats, when compared to the PCV gold standard.
3. To study the relationship between some serum biochemical indicators of nutritional status and FAMACHA© scores in goats.
4. To determine the prevalence of hemo- and ectoparasites as possible contributors to anemia in goats.

1.6 Research Hypothesis

The hypothesis to be tested is that:

There is no relationship between the FAMACHA© scores, fecal egg counts, PCV, some nutritionally related blood metabolites and clinical anemia in RS goats.

1.7 Scope and Limitation of the Study

The FAMACHA©system was designed to be applied on animals in a farm setting and it is desired that each animal be scored at specific intervals over a period of time. Due to time and

financial constraints as well as unavailability of an organized farm where the study could be carried out, the study was narrowed down to a preliminary evaluation of animals presented for slaughter. The results obtained from this study are expected to pave the way for further work on validating the use of the FAMACHA©system in Red Sokoto goats.

CHAPTER TWO

LITERATURE REVIEW

2.1 Etiology of Haemonchosis

Sheep, cattle and goats are all affected by haemonchosis. *Haemonchus contortus* is the species most commonly found in sheep and goats. It inhabits the abomasum and is easily seen, being 1-2.5cm long and relatively thick. *Haemonchus placei* also develops well in sheep and causes clinical haemonchosis but of less severity than that caused by *H.contortus. H. placei* is the species usually found in cattle, and also inhabits the abomasum. *H. contortus* may also be present but usually only when the cattle are grazing the same pasture as sheep or goats. The infestations are usually not as heavy and are eliminated sooner than *H.placei* infections (Dwight, 2003).

2.2 Classification and Biology of *Haemonchus contortus*

Haemonchus contortus is a nematode belonging to the Phylum Nemathelminthes, Class Nematoda, Super Family Trichostrongyloidea and Family Trichostrongylidae. Like other members of the Super Family, it is a bursate nematode (Blood *et al*., 1989; Dwight, 2003).

The parasite occurs in the abomasum of sheep, goats, cattle and other ruminants in most parts of the world. It is commonly known as the 'stomach-worm', 'wire worm' or 'barber's-pole worm' of ruminants. It is one of their most pathogenic parasites. Males are 10-20mm long and females 18-30mm. The male has an even reddish color, while in the female the white ovaries are spirally wound around the red intestine, producing the appearance of a barber's pole. The cervical papillae are prominent and spine-like. A small buccal cavity is present, containing a dorsal lancet (Plate I). The male bursa has elongate lateral lobes supported by long, slender rays; the small dorsal lobe is asymmetrically situated against the left lateral lobe and supported by a Y-shaped dorsal ray (Plate II). The spicules are 0.46-0.506 mm long, each

provided with a small barb near its extremity. The vulva of the female is usually covered by a linguiform process (vulva flap), which is usually large and very prominent. The eggs measure 70-85 by 41-48 µm, and those passed in the feces of the host contain an embryo divided into 16-32 cells (Soulsby, 1982).



Plate I: Photo plate showing the dorsal lancet in the buccal cavity at the anterior part of *Haemonchus contortus*.

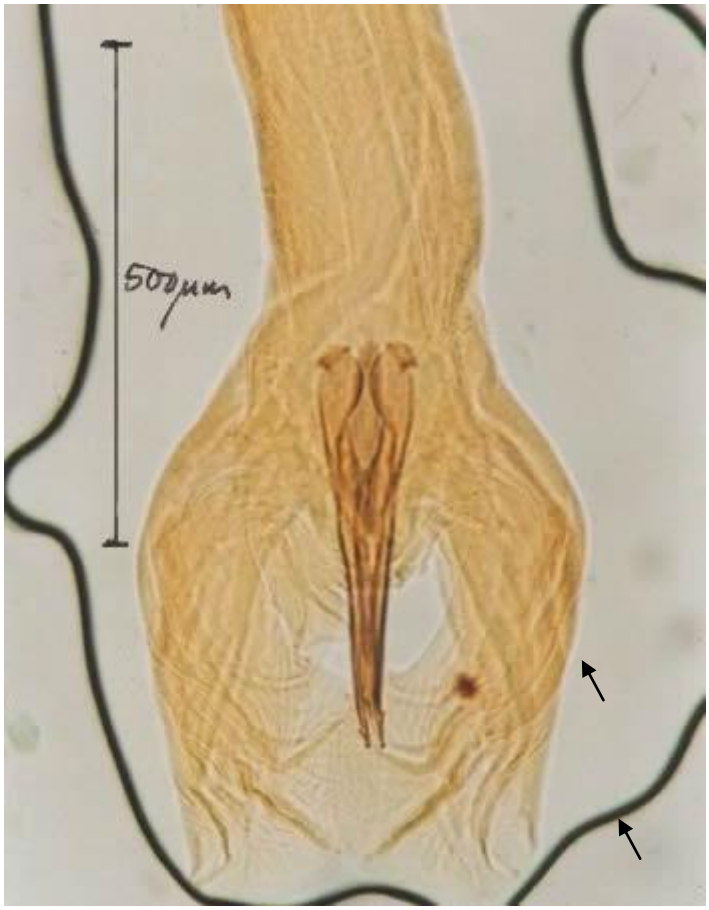


Plate II: Photo plate showing the spicules and bursal rays in the male bursa (upper and lower arrows respectively) of *Haemonchus contortus*.

2.3 Life cycle of *Haemonchus contortus*

The life-cycle of the parasite is simple. According to Dorny *et al*. (1996), the female worm can release between 5,000 and 10,000 eggs, which will be passed out in the feces. Eggs then develop in moist conditions in the feces and continue to develop into the first and second larval stages (L_1 and L_2) respectively, by feeding on bacteria in the dung. The L_1 stage usually occurs within four to six days under the optimal conditions of 24-29°C (Wharton, 1982). The rhabditform L_2 sheds its cuticle and then develops into the L_3 filariform infective larvae. Under satisfactory environmental conditions, infective larvae are reached in 4 to 6 days. Low temperatures retard development and below 9°C little or no development takes place. Eggs

which have reached the “pre-hatch” stage are more resistant to adverse conditions and can survive freezing and desiccation more readily than other stages. However, the eggs and infective larvae of *H.contortus* are intolerant of desiccation and low temperatures (Wharton, 1982).The L_3 form has a protective cuticle, but under dry, hot conditions will not survive long. The L_3s then crawl up the blades of wet grass and wait to be ingested by a grazing animal. Depending on temperature and moisture, L_3 larvae can survive on pasture up to 6 months (Maxie *et al*., 2007).Sheep, goats and other ruminants become infected when they graze and eat grasses containing the L_3 infective larvae. The infective larvae pass through the first three fore stomachs, where they exsheat (that is, shed their cuticles). They then migrate to the abomasum and penetrate between the gastric epithelial cells, from where they later will emerge as the fourth-stage larvae (L_4), usually within 48 hours. The L_4 then molt and develop into the L_5 which matures into the adult form. The male and female adults mate and live in the abomasum, where they feed on blood (Dorny *et al*., 1996; Roberts and Janovy, 2000). The prepatent period of *H.contortus* in sheep and goats is 15 days (Soulsby, 1982).

It has been reported that in Nigeria, larvae of *H. contortus* undergo arrested development to survive the dry season. Inhibited larvae represent 14% of the *H.contortus* burden in June to July, 55% in August and 95% by October (Ogunsusi and Eysker, 1979).

Resumption of development of arrested larvae occurs at a time when environmental conditions are suitable for the survival of the free-living stages and is possibly associated with a seasonal stimulus. Larvae resume development primarily at the beginning of the rainy season in Nigeria (Ogunsusi and Eysker, 1979).

2.4 Clinical Pathology

The nematodes piercing the abomasum cause a number of significant complications in the infected ruminants that can lead to death. Typical clinic- pathological findings include anemia, hypoproteinemia, and eosinophilia (Maxie *et al*., 2007). In one experimental study, mean Packed Cell Volume dropped to 15% in infected sheep 35 days after infection, and mean eosinophil count increased from <5% to 25% of circulating white blood cells 56 days after experimental infection. Eosinophilia decreased from days 63-77 of the experiment, which may have resulted from localization of eosinophils in the abomasum. A significant correlation between eosinophilia and worm burden has been demonstrated (Jacobs *et al*., 1995).

2.4.1 Gross lesions

Grossly, animals with haemonchosis have marked pallor of mucous membranes and internal tissues. A characteristic gross lesion is widespread subcutaneous edema (Jacobs *et al.*, 1995). This may be most striking in submandibular soft tissues producing the so-called “bottle-jaw”. Edema is concentrated in the submandibular soft tissues because the head is often dependent in grazing animals. Hydrothorax, hydropericardium and ascites are other sequelae of hypoproteinemia as is edema of the abomasal mucosa. Lymph nodes draining the abomasum may double in weight within five days of infection (Maxie *et al*., 2007; Jacobs *et al*., 1995).

The abomasum usually has dark red-brown contents with multifocal mucosal hemorrhages and *H. contortus* adults. In a freshly dead animal, the worms are often alive and writhing; if the animal has been recently treated with anthelmintics, worms may not be found (Bath, 2011).

2.4.2 Histopathologic lesions

Common histologic lesions include interstitial edema in many organs and centrilobular hepatic necrosis, which are believed to be sequelae of the hypoproteinemia, anemia, and resultant hypoxia. Abomasitis may be seen with increased number of mucosal lymphocytes, eosinophils, and mast cells. The local immune response in the abomasum has been studied for vaccine development, which is of particular interest in the face of increasing anthelmintic resistance (Jacobs *et al.*, 1995).

2.5 Clinical Signs and Diagnosis

Clinical diagnosis of haemonchosis is made based upon the characteristic clinical signs of anemia, submandibular edema, and weight loss (Kaplan, 2005). Affected animals can also display severe dehydration, unthrifty appearance, lethargy, rough hair coat and uncoordinated movements. Furthermore, significantly reduced growth and poor reproductive performance have been observed (Dorny *et al.*, 1996).These signs are usually supported with finding large number of eggs in the feces, since the female worms produce approximately 5000-10000 eggs per day, and goats can be infected with thousands of these worms (Kaplan, 2005). According to Maxie *et al*. (2007), clinical observation is perhaps the most useful tool in diagnosing and managing haemonchosis, although this requires close examination. Because anemia is the principal clinical problem, mucous membrane pallor is one of the easiest ways to monitor the animals, and has proven effective as a diagnostic approach. The FAMACHA© system which uses a 5-point scale to gauge ocular mucous membrane color, has been shown to correlate with Packed Cell Volume values in sheep and goats (Kaplan, 2005).

2.6 Immunity against Parasites

Immunity, or host resistance, as it applies to nematode parasites is the ability of an animal to prevent infection with parasites, and or reject established parasites in the animals, utilizing both innate and acquired immune responses (McClure, 2000). Innate immunity is inherent, whereas acquired immunity gradually develops in the hosts when they are exposed to the parasites. During their first season at pasture, calves, lambs and kids acquire strongylid burdens rapidly by ingesting third-stage larvae as they graze. If the vegetation is heavily contaminated with highly pathogenic species (e.g., *H.contortus* or *O. ostertagi*), disease and deaths may occur among these young and inexperienced hosts. The accumulation of infection is manifested by a corresponding increase in fecal egg output and by further contamination of the pasture. Provided with sufficient warmth and moisture for larval development, the number of infective stages will tend to increase exponentially, at least during the early part of the grazing season. However, the hosts now begin to develop resistance to further infection.

2.6.1 Premunition

Premunition is defined as "a state of resistance to infection which is established after an acute infection has become chronic and which lasts as long as the infecting organisms remain in the body" (Dorland, 1988). The mechanism of premunition is unknown, but the phenomenon can be readily demonstrated by a variety of simple experiments. According to Dorland (1988), if we decide to impose a severe *H. contortus* burden on a sheep that is already harboring a moderate population of these parasites, we must first remove the already established population by anthelmintic medication. Otherwise, part or the entire dose of the larvae we administer experimentally will fail to take (Dorland, 1988).

An ecological explanation of premunition was given on the basis of kin selection, that is, worms once established exploit the chosen niche and somehow directly or with the

manipulation of the host make the niche inhospitable to other worms from different parental stock. When sheep are infected first with one group of worms and then infected with genetically related worms after the first group has matured, there is some evidence that the genetic relatedness of the existing and incoming populations has an effect on the number of worms that will develop to adulthood (Ketzis *et al*., 2001). Removal of this stable adult population by anthelmintic medication vacates an ecological niche that is promptly filled through maturation of arrested larvae, uninterrupted development of recently ingested infective larvae, or both (Ketzis *et al.*, 2001). For this reason, a ruminant with a subclinical strongylid infection should not be treated with anthelmintics unless an uncontaminated environment can be provided after treatment. The loss of premunition resulting from removal of the stable and established infection will permit rapid reinfection, perhaps with a heavier parasite load than before .This phenomenon further shows the need for investigation into the FAMACHA© system, which practically discourages the practice of herd or flock anthelmintic medications for helminth control. As premunition and other forms of host resistance develop, individual strongylid burdens reach a peak and then begin to decline. Most adult ruminants exhibit naturally acquired protective immunity to gastrointestinal nematodes (McClure, 2000).

2.6.2 The self-cure phenomenon

Another form of immunity that persists to protect the host against reinfection after the initial strongylid population is gone has also been demonstrated. Stoll (1929) reported an experiment "in which two helminth-free lambs, upon fenced-in pasturage permitting natural repeated infection, during the summer developed, following an initial dose of *Haemonchus contortus* larvae, first an accumulation of parasites and then a self-cure which expelled the worms and protected the animals thereafter against any significant amount of further infestation with this stomach worm". Thus was born the celebrated phenomenon called *self-cure*. It is simply defined as the elimination of a burden of parasites as a result of an immune response on the

part of the host (Stoll, 1929). Little was done to try and describe the phenomenon more precisely until Stewart's work some twenty years later (Stewart, 1950a, b, c, 1953; 1955), which made it possible to describe the mechanism in much more detail. Working largely with *H.contortus* Stewart showed:

(1) That the reaction was precipitated in an animal harboring a population of adult worms by the intake of a new dose of infective larvae.

(2) That it did not occur in all infected sheep challenged with larvae but it was most likely to occur in animals which had had several previous infections with *H.contortu*s and were showing good 'immediate-type' skin reactions to *Haemonchus* antigens.

(3) That in some cases adult worm population was largely eliminated, in others the 'self-cure' was partial in that only a proportion of worms was thrown out and indeed on some occasions all that was produced was a transient suppression of egg production.

(4) That the reaction was not completely specific, e.g. when sheep infected with both *H.contortus* and *Ostertagi* species were challenged with *H.contortus*larvae, adults of both parasites were thrown out. Furthermore it was not even necessary that both parasites should occupy the same locus. When the 'self-cure' of an *H.contortus* infection took place, *T. colubriformis* were also eliminated from the small intestine. On the other hand the converse was not true- the intake of *T.colubriformis* had no effect on abomasal parasites.

It is quite clear that this is a phenomenon of great practical importance. It is of considerable value to the grazing animal to be able to get rid of a substantial proportion of its adult parasite burden. Much of the work on the mechanism of the reaction has again been carried out by Stewart and his colleagues. The suddenness of onset, the association with a good 'immediate-type' skin reaction, and the fact that some antihistaminics (Anthisan) appeared to interfere with the 'self-cure' suggested that a local anaphylactic reaction might be occurring in the

abomasum which would lead to the elimination of the worms. There is some evidence to support this view. When abomasa of suitable sheep were exposed by laparotomy and exsheathed *Haemonchus* larvae injected, changes were observed involving increased peristalsis and the development of edema. Control sheep showed no such changes (Soulsby and Stewart, 1959).

2.6.3 Practical significance of self-cure

According to Dwight (2003), there is at least one definite practical consequence of 'self-cure'. Sheep and goats may die in the throes of evicting their worms and confuse the diagnosis by being found "uninfected" at necropsy when clinical signs and history correctly pointed to haemonchosis. Profound anemia in grazing sheep or goats is usually due to haemonchosis unless positive evidence of another cause can be produced. The absence of *H.contortus* worms from the abomasum of an anemic sheep or goat in no way rules out the diagnosis of haemonchosis.

Unlike in bacterial infections, where vaccinations and natural boosting often produces high levels of acquired immunity, young sheep infected by gastrointestinal nematodes are unable to respond as early or as profoundly (Jacobs *et al*., 1995; McClure, 2000). It has also been reported that this form of protection is partial, as parasites are also present after immunity has developed. The doses of larvae ingested as well as the species of the parasites are some known parameters that affect the rate at which immunity develops (Dobson *et al*., 1990). Resistance has been described as the ability of the host to prevent or limit the establishment of infection. Resilience is the ability of an animal to maintain a reasonable level of production when subjected to parasitic challenge (Van Houtert and Sykes, 1996). Considerable research have been undertaken in many countries where sheep are produced to identify breeds that have natural resistance to gastrointestinal nematode infections, a typical example being the Merino sheep of Australia (Woolaston and Baker, 1996; Raadsma *et al*., 1998).

2.7 The Anemia in Helminthosis

Of the helminthes which cause anemia as the result of bloodsucking activities, the best known are the hookworms and *Haemonchus* species. Other parasitic diseases, such as schistosomiasis accompanied by capillary rupture and fascioliasis with extensive liver destruction, may result in significant blood loss (Clark *et al*., 1961).

2.7.1 Normocytic anemia

The normocytic anemias result primarily from acute blood loss, blood destruction, and bone marrow hypoplasia (Wintrobe, 1961). Of all the anemias that occur in helminth diseases, normocytic anemias, at least in the early stages of the disease, are by far the most common. In most instances the mechanism by which the anemias are produced is quite clear-cut, being due to the blood sucking propensities of the parasite. Clinically, however, the course of the disease often progresses to the point that the condition becomes one of chronic blood loss with the ensuing development of a microcytic hypochromic anemia (Wintrobe, 1961; Von Bonsdorff, 1956). It has been reported that where blood loss through hemorrhage occurs the primary loss of iron occurs from the circulating erythrocytes. Consequently, the avoidance of anemia would require an equally great increase in the amount of iron supplied to the bone marrow from the storage pools in the liver and spleen and (or) that from absorption with subsequent effective erythropoiesis compensating for the loss. In general, such a rapid compensation cannot occur and as a result a normocytic anemia results (Fourie, 1931).

2.7.2 Microcytic and Macrocytic anemia

During the very early stages of blood loss, there may be an equally great loss of plasma and routine peripheral blood studies may not indicate the anemic change. As extravascular fluids enter the vascular system, however, the deficiency of red blood cells will be expressed in reduced erythrocyte count, hemoglobin, and Packed Cell Volume (Clark *et al*., 1962). Since the

total amount of iron that can be absorbed is limited, a continued loss of red blood cells (chronic hemorrhage) of sufficient amount will ultimately result in depletion of storage iron and the anemia will become hypochromic microcytic in type. The response to acute blood loss will usually be accompanied by the release of reticulocytes and, in some instances, other immature erythrocytes which have a greater mean corpuscular volume and may thus result in a transitory macrocytic anemia (Wintrobe, 1961; Clark *et al.*, 1962).

2.7.3 The anemia due to haemonchosis

Haemonchus contortus has been shown to produce disease primarily by extraction of the host's blood (Fourie, 1931; Boughton and Hardy, 1935; Andrews, 1942; Baker *et al.,* 1959, Clark *et al.,* 1962). Research has shown that early in the disease, there is a reduced erythrocyte count, a decreased hemoglobin level, and a reduced Packed Cell Volume. The volume and color indices of the red cells are increased and, on examination of stained blood smears, anisocytosis, polychromasia, and an increased number of reticulocytes are found. Examination of bone marrow indicates that active erythropoiesis and a myeloid hyperplasia occur, all of these processes being indicative of an acute blood loss prior to the development of iron deficiency.

Andrews (1942) found that in two fatal cases of haemonchosis 1.57 and 2.5 times the total blood volume were lost in the feces during the course of infection. In a related experimental study, Martin and Clunies-Ross (1934) calculated that 2000 females would require a minimum of 29 ml of blood per day for egg production alone. Such figures are in good agreement with those reported by Baker *et al*. (1959) and Clark *et al*. (1962). As the infection progresses the peripheral hemogram changes to one of poikilocytosis, hypocromacia, and decreased MCV. Such changes were interpreted by Fourie (1931) as indicating exhaustion of the hemopoietic tissues.

2.8 Resistance to Anthelmintics by Helminth Parasites

2.8.1 Definition of drug resistance

Resistance is said to exist when the greater percentage of individuals within a population is able to tolerate doses of a drug compound than in normal population of the same species (Prichard *et al*., 1980).

2.8.2 Factors responsible for anthelmintic resistance

According to Geerts and Dorny (1995), factors responsible for anthelmintic resistance include mass treatment, frequent use of the same class of drug over prolonged periods and under-dosing. The relative high cost of anthelmintics in the developing countries has resulted in the tendency of farmers to under-dose animals in an attempt to treat many animals, thus contributing to the development of resistance (Fieldings, 2000). The availability of fake and adulterated anthelmintics in the drug market in many of the under developed countries is another important contributing factor to the development of resistant strains (Monterio *et al*., 1998).

2.8.3 Early reports of anthelmintic resistance

The earliest reports of anthelmintic resistance were made shortly after the introduction of thiabendazole in the 1960's (Conway, 1964; Drudge *et al.*, 1964). Since then, there have been several other reports of anthelmintic resistance in cattle, sheep, goats and equine from many countries. Beveridge *et al*. (1990) found high level of benzimidazole and levamisole resistance in *H.contortus*, *Nematodirus* spp, *Ostertagia ostertagi*, *Trichostrongylus axei* and *T. colubriformis* in Southern Australia. Borgesteede *et al.* (1991) reported increasing incidence of anthelmintic resistance of sheep in the Netherlands. Uhlinger *et al*. (1992) also reported that

there was benzimidazole resistance in *H.contortus* in sheep in North Carolina. In the U.S.A., ivermectin resistance has been reported in *H.contortus* (Egerton *et al*., 1988) and *T.colubriformis* in sheep (Giardino *et al.,* 1988) in experimental infections.

2.8.4 Anthelmintic resistance around the world

Under field conditions, ivermectin resistance was noticed in *H. contortus* in sheep and goats in South Africa (Carmichael *et al*., 1987; van Wyk *et al.,* 1987*;* van Wyk and Malan, 1988), in Brazil (Echevarria and Trindale, 1989; Echevarria *et al.*, 1991) and in the USA (Craig and Miller, 1990; De Vaney *et al*., 1992). In Nigeria, Obemeaser *et al.* (1997) reported anthelmintic resistance due to incorrect dosage and improper regimen of anthelmintic administration by farmers. Fashanu and Fagbemi (2003) and Mbah *et al*., (1992) also reported benzimidazole resistance in strongyles.

2.8.5 Diagnosis of anthelmintic resistance

Conventionally, anthelmintic resistance is diagnosed by comparison of egg count and post-mortem worm count of treated and untreated animals, *in vitro* egg hatch test and *in vivo* motility assays (Prichard, 1994). Once anthelmintic resistance is confirmed in any herd or flock, it is usually advisable to change the drug to a different class of compound with a different mode of action.

2.9 Selective Treatment and the Use of FAMACHA©

2.9.1 Selective treatment

Selective treatment simply means deciding which animals to deworm at a particular time, rather than whole-herd treatment. This is the newest approach to smart drenching and is probably the most important component of a program designed to delay the development of resistance. The reason for this is that the most important factor affecting the rate of selection

of anthelmintic resistance is the size of the unselected proportion of the population (Sangster, 1999; Van Wyk, 2001). This unselected population, referred to as refugia, provide a pool of sensitive genes, thus diluting the frequency of resistant genes in a population of worms. In practical terms, refugia would be all the infective larvae already on pasture at the time of treatment and the worms in hosts that are left untreated with anthelmintic. The larger the refugia, the slower the evolution of resistance. Parasitologists now believe that one of the major factors leading to the rapid and widespread development of anthelmintic resistance is the common practice of treating all animals at one time. This practice leaves no worms in refugia; the only eggs to hit the pasture for several weeks following treatment are from those worms that survived treatment. It has also been observed that if treatments are given when few infective larvae are on pasture, (early in grazing season or during drought), then eggs shed by the resistant worms that survived the treatment are not greatly diluted. This gives these resistant larvae an even greater chance of re-infecting their hosts (Van Wyk, 2001).

Burke and Miller, (2008) and Kaplan *et al.* (2004) reported that worm burdens are not evenly distributed in animal populations; 20% of the animals harbor about 80% of the worms. These 20% are primarily responsible for contaminating the environment with infective larvae for all the other animals. If only those 20% could be identified and treated, the parasites could be controlled, money would be saved by reducing the number of treatments given on a herd basis, and the selection for resistance would be greatly lessened by maintaining a large refugia. The question then becomes, how can those animals that require treatment be accurately identified?

2.9.2 The FAMACHA©system

The FAMACHA© system is a clinical on-farm system for classifying animals into categories based upon level of anemia and was developed by a group of Veterinarians and Scientists in

South Africa. This system has been named the FAMACHA©chart system, after its iniator, Dr. Francois Faffa Malan (Kaplan *et al*., 2004). Since anemia is the primary pathologic effect from infection with *H.contortus,* the FAMACHA© system can be an effective tool for identifying those animals that require treatment. To use FAMACHA©, farmers observe the color of ocular mucus membranes of the animals and compare this color to a laminated card with illustrations of eyes from sheep at different levels of anemia. The card (Plate III) is calibrated into 5 categories: 1= red, non-anemic; 2= red-pink, non- anemic; 3= pink, mildly- anemic; 4= pink-white, anemic; 5 = white, severely anemic (Kaplan, 2005). The lighter the color, the more anemic an animal is. Anemia occurs as a result of the parasite removing more blood than the animal can replace. There may be other causes of anemia, so the farmer must be aware of the health and nutrition status of his animals. Animals with red color can be left untreated, whereas paler scores indicate that an animal should be treated. Since it is known that 20% of the flock/herd carry 80% of the worms, or in other words, 20% of the animals consistently are more susceptible to infection with *H. contortus*, carry the worms and distribute the eggs in the pasture, identification of these animals is possible partly through the use of FAMACHA© and these animals can be culled or removed from the population. It is possible to develop a more resistant group of animals that need less frequent treatment for parasites (Kaplan *et al*., 2004; Burke and Miller, 2008). FAMACHA© examination should occur more frequently on weaned lambs / kids and late pregnant / early lactation ewes / does. The immune system becomes depressed around the time of lambing / kidding, which leaves the animal more susceptible to parasites (Kaplan *et al*., 2004).

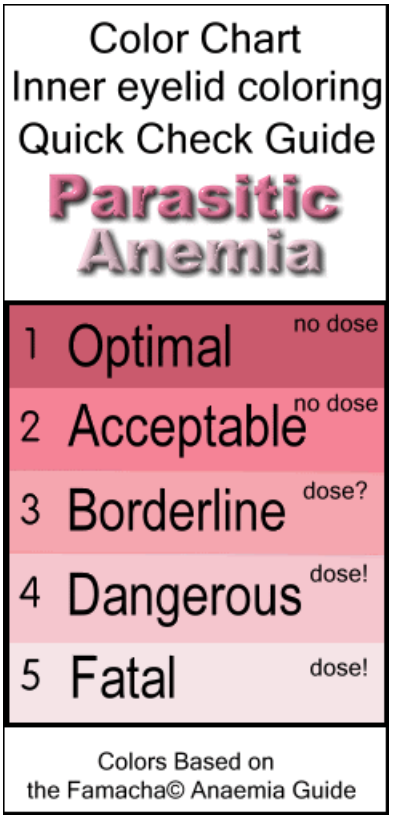


Plate III: Photo plate showing the FAMACHA© anemia chart.

2.10 Advantages and Disadvantages of the FAMACHA© System

The advantages of the FAMACHA© system include reduced expenses for anthelmintics as number of annual treatments will be lower and, if selective treatment is practiced, the number of animals treated will be lower. Also, the possibility of selecting for anthelmintic resistance is significantly reduced, if only some animals are treated, as this will ensure the presence of a susceptible parasite population. Another advantage is the fact that the method is easy and cheap to apply for continuous monitoring and it is easily taught to farmers. The use of pictures and signs makes it suitable for illiterate farmers (Van Wyk *et al*., 2006). On the other hand, the system is also known to have some disadvantages such as the need for intensive labor input for regular monitoring of the animals. The fact that the system only applies to infection with *H.contortus,* neglecting other possible causes of anemia in sheep and goats is also a notable disadvantage (Van Wyk *et al*., 2006).

2.11 Measures of Assessing Nutritional and Health Status of Goats

Early proper diagnosis of diseases is a pre-requisite to reduce losses in goat production (Tibbo *et al.*, 2004). Methods that can be employed in determining health and nutritional status of goats include body weights and condition changes, worm burdens, packed cell volume, the FAMACHA© technique and use of blood metabolites of nutritional value (Tibbo *et al*.,2004).

2.11.1 Body weights and condition scoring

Many authors have reviewed the use of body weights and condition scores in the determination of health / or nutritional status of livestock (Oulun, 2005; Sakkinen *et al*., 2005; Ndlovu *et al*., 2007). Cisse *et al*. (2002) reported that body condition score is an indication of body fats more than body weight. Moreover, since most resource - poor farmers do not have scales for weighing their goats, research should focus on the applicability of body condition scoring as a health and / or nutritional status indicator in the communal goats. Of importance are relationships that exist between body condition and weights on one hand and other parameters such as egg worm counts on the other hand, with the main aim of determining the best method to use in the assessment of health and nutrition status of goats (Morand-Fehr, 2003; Mannathoko, 2002).Body condition scoring had been proposed as an adjunct to FAMACHA© and a feasible tool for assessing bankrupt worm (*Trichostrongylus* spp.), brown stomach worm (*Telodorsagia circumcinta*), and other non-haematophagous worm infections in small ruminants (Bath *et al*., 2001; Idika *et al*., 2012). Body condition scoring is generally considered the best and simplest indicator of available fat reserves which can be used by the animals in periods of high energy demand, stress or sub-optimal nutrition which are characteristic of GI nematode infections (Coop and Kyriazakis, 2001).

2.11.2 Fecal egg counts

An estimation of the numbers and species of eggs, larvae or oocysts produced by endo-parasites infecting the liver, digestive and reproductive tracts of goats is a practical aid to the diagnosis of gastrointestinal parasitism (Aitken, 2007). Results obtained can be of immense value in the provision of epidemiological evidence for the time of build-up of high levels and survival of nematode parasites in goat flocks. Information obtained could also be useful in designing strategies for control of prevailing helminthes (Githigia *et al*., 2001).

Fecal egg counting is the most common ante-mortem means of diagnosis for helminthosis (Kusiluka and Kambarage, 1996). Eggs are, however, less valuable in drawing conclusions about clinical conditions of an individual goat. This might be ascribed to many factors that affect the level of egg production, such as the consistence of the feces may affect the number of eggs per gram of feces markedly as the more watery the feces are, the more diluted the eggs are. Biotic potential of the nematode species, season of the year, and resistance of the host and developmental stage of the parasite also influence the number of eggs per gram. The prevalence of goats infested with strongyles in communal areas is variable. In a Nigerian goat flock, Nwosu *et al.* (2007) observed 35.4% of the goats to be positive for strongyles. But in other related studies, (Chiejina *et al*., 2002; Mbuh *et al*., 2008), strongyle prevalence ranged from 77 to 100%. The variation in the strongyle prevalences can possibly be due to factors such as climate and production system (Nwosu *et al*., 2007). It, therefore, is imperative to determine the parasite load and the prevalence in goats in each communal area.

The identification of parasite species present in a goat flock is an important component of the investigation of clinical diseases caused by gastrointestinal parasites (Papadopoulos *et al.*, 2007). As important as eggs per gram is in diagnosis, a more specific diagnosis of helminth infections can be obtained by culturing the eggs to yield third stage larvae which can be identified to generic level. Examples are eggs from species such as *H.contortus*, and

*Trichostrongylus spp.*which are generally known as strongyles (Sissay *et al*., 2006). Their infective larvae differ morphologically (Kusiluka and Kambarage, 1996) and their examination permits a specific diagnosis of nematode infections. Estimation of infective larvae population provides a clue of the intensity of infestation to which grazing goats are exposed. The larval population on herbage is dependent on stocking density; rainfall and herbage cover (Kusiluka and Kambarage, 1996). Unfortunately, often due to the land tenure system prevailing in most communal areas and the high cost of acquiring and maintaining tracer goats deter utilization of this method by resource poor-farmers. Therefore other parameters such as Packed Cell Volume can be considered in the assessment of the status of goats (Kusiluka and Kambarage, 1996).

2.11.3 Packed Cell Volume

Packed Cell Volume (PCV), the proportion of erythrocytes expressed as a percentage of the volume of whole blood per given sample (Kusiluka and Kambarage, 1996), is the most precise means of determining red blood cell volume and can be used to deduce total blood volume and hemoglobin levels. Analysis of normal hematocrit values is fundamental in diagnosing the various pathological and metabolic disorders (Grunwaldt *et al*., 2005). Low Packed Cell Volume is indicative of anemia, hemorrhage, bone marrow failure, leukemia, malnutrition or specific nutritional deficiency, multiple myeloma and rheumatoid arthritis (Kaneko, 1997). Packed Cell Volume values higher than the reference values could indicate dehydration due to diarrhea, erythrocytosis and polycythemia vera. In goats, it has been shown that PCV is influenced by sex and altitude (Tibbo *et al*., 2004), management, age (Grunwaldt *et al.*, 2005), breed, health status, ambient temperature, and physiological status such as excitement, muscular exercise, pregnancy, estrus, parturition, water balance and transportation (Kaneko, 1997). Diurnal and seasonal variations also modulate PCV values (Osaer *et al.,* 2000). Reduced oxygen tension, in mountainous regions, leads to an increased production and release of erythropoietin, thereby,

stimulating erythropoeisis as an adaptive mechanism to low oxygen level in such an environment (Tibbo *et al*., 2004). Therefore, the higher PCV values exhibited in indigenous (South African) breeds in a study by Tibbo *et al.* (2004) under high altitudes (1650 and 2800 m above sea level) could provide evidence of adaptation of these breeds to low atmospheric oxygen. This might signify that climbing of mountains by such adapted goats, in search of feed, might not affect the physiology of the goats. Higher PCV values observed in does than bucks might be attributed to various physiological factors associated with females (Tibbo *et al.,* 2004). For example, during estrous does are in a restless and excited condition, where splenic contraction may increase the erythrocyte values.

Daramola *et al*. (2005) and Taiwo and Ogunsanmi (2003) reported different PCV values for clinically healthy West African Dwarf goats, signifying that many other factors, apart from breed, greatly influence Packed Cell Volume.

2.11.4 Detection of anemia

Haemonchosis can develop so rapidly that a reduction in body condition or body weight will likely not be apparent during an acute infection. Vatta *et al*.(2002) indicated that body condition score (BCS) on its own is not a good indicator of infection with *H.contortus.* In another study, Vatta *et al.* (2001) reported that there was no relationship between BCS and FEC whilst Roberts and Swan (1982) found no correlation between body weight and worm counts when *H.contortus* was the predominant nematode. This indicates that other methods of assessment of goat health and productivity should be implemented, in situations where *H.contortus* is the main gastrointestinal parasite, to increase the efficiency of identification of goats in poor health. One such option is the FAMACHA© system (Kaplan *et al.*, 2004) which was developed in South Africa for classifying sheep into categories based on different levels of anemia (Bath *et al.,* 2001).The FAMACHA© has since been used on goat flocks in countries such

as South Africa (van Wyk *et al.,* 2006) and southern USA (Kaplan *et al*., 2004; Burke *et al.,* 2007), and recently Nigeria (Glaji *et al.,* 2008 and Idika *et al.,* 2012). These trials have confirmed the practicability of this technique on-farm application. The effectiveness of the technique has been evaluated in identification of parasite - resilient and / or resistant breeding bucks, and thus identification of stud rams with greater resilience / resistance (Burke and Miller, 2008) to gastrointestinal parasites. The use of this system may be recommended as part of an integrated approach to worm control in goats kept by resource-poor farmers. Although the FAMACHA© system is useful in predicting the health status of goats, it cannot be used in isolation since it only detects presence of *H.contortus* in a goat flock. It, therefore, implies that it should be coupled with methods such as use of blood metabolites, in predicting the condition of the goat.

2.12 Determination of health and nutritional status of goats using blood metabolites

The chemical constituents of blood have been shown to assist in the assessment of the health and nutritional status of goats in Southern Africa. Metabolic profiling has been applied in Saanen goats (Bagliacca *et al.,* 1988), African Dwarf goats (Lohle, 1994) and Mozambican goats (Harun *et al.,* 1996).

2.12.1 Blood chemical constituents related to carbohydrate and lipid metabolism

Blood glucose, β-hydroxy butyrate and non-esterified fatty acids are the most common metabolites used to assess the energy status of animals. Due to homeostatic regulation, blood glucose has a moderate variability and, therefore, has an intermediate diagnostic value in the assessment of nutritional status of goats. Lowered feed intake results in decreased blood levels of propionate and other glucose precursors derived from the diet resulting in a reduction of the rate of glucose synthesis (Reynolds *et al*., 2003). The energy metabolism of goats is largely dependent on the utilization of volatile fatty acids as an energy source (Kaneko,

1997; Agenas *et al*., 2006). The growth rate of animals influences glucose requirement (Zubcic, 2001; Reynolds *et al.,* 2003) whereas in mature animals only maintenance energy is required.

Glucose concentrations were reported to be lower in lactating than in non-lactating does during the first two months of lactation (Pambu-Golla *et al*., 2000). Although feed quality also affects blood glucose levels, an increase in body temperature and respiration rate of animals normally experienced in the hot-wet season leads to a reduction in blood glucose in cattle (Grunwaldt *et al.,* 2005). It is not known if goats are also affected in the same manner.

Lipids that are important in the assessment of nutritional status of goats are non-esterified fatty acids (NEFA), β-hydroxybutyrate (BHB), cholesterol, and lipoproteins. There is low variability in the blood levels of non-esterified fatty acids as compared to cholesterol which has a moderate variability (Sakkinen, 2005). Elevated NEFA levels indicate dietary energy deficit. Concentration of NEFA then directly reflects the amount of adipose tissue breakdown taking place (Caldeira *et al*., 2007). Circulating NEFAs are absorbed and metabolized for energy by the liver and other tissues. Beta-hydroxybutyrate (BHB) is a ketone body with a high prognostic value due to its low variability in serum or plasma. Blood ketone bodies are elevated in association with poor carbohydrate status in circumstances related to a negative energy balance (Agenas *et al*., 2006). Beta-hydroxybutyrate elevated concentrations indicate short-term negative energy balance and adipose tissue catabolism. However, BHB concentrations may not be predictive enough and may arise from dietary sources (Agenas *et al.*, 2006).

Cholesterol, a major constituent of animal cell membranes, is of endogenous origin. It arises from acetate from the adipose tissue and small intestines (D'Mello, 2000). High plasma cholesterol concentrations in the absence of excess dietary energy intake are considered to reflect the capacity of the animal to mobilize body fat reserves. Physiological status of a goat affects cholesterol levels. Iriadam (2007) reported an increase in blood cholesterol in goats from 104 mg/dl in early pregnancy to 110.67mg/dl and 114.87 mg/dl during mid and late

pregnancy respectively. The increase in cholesterol levels with advancing pregnancy is ascribed to stress which predisposes the animal to gluconeogenesis with an associated rise in transaminases. The elevated levels of transaminases result in a higher level of cholesterol (Iriadam, 2007). The elevated levels of cholesterol, triglycerides, and phospholipids, however, could be indicative of copper deficiency. The essential nature of copper is due to its cofactor role at the active site of a number of enzymes (Cham *et al*., 2005).

2.12.2 Blood chemical constituents related to protein metabolism

The total protein (TP) concentration represents all proteins dissolved in blood plasma or serum (Sakkinen, 2005). Albumin, synthesized in the liver from amino acid derivatives is responsible for the colloid - osmotic pressure that inhibits leakage of blood plasma from capillaries into tissues (Kaneko, 1997). Protein deficiency impairs both humoral and cell- mediated immunity, thus predisposing an animal to diseases (Tietmeyer *et al*., 2001). Blood TP and albumin concentrations indicate the nutritional conditions in domestic ruminants (Kaneko, 1997) due to their stability in blood. Low levels of albumin and TP in plasma are interpreted as protein deficiency and under nutrition. Seasonal variations in TP and albumin have, therefore, been ascribed to changes in the quality and quantity of diet (DelGiudice *et al*., 1992).

Plasma albumin is considered a general indicator of nutritional status, related to both feed intake and body weight (Sakkinen, 2005). Albumin levels are affected by physiological status of the goat. Celi *et al*., (2008) indicated that albumin levels were higher three weeks before kidding compared to four weeks after kidding in goats. Due to the long half - life of albumin (Kaneko, 1997), inadequate dietary protein intake leads to a slow, gradual decrease in the blood albumin concentration when insufficient amino acids are supplied to the liver cells for albumin synthesis. Therefore, the plasma albumin is a long - term measure of protein status in ruminants (Agenas *et al*., 2006).

The effect of under - nutrition on serum globulins is highly modulated by the duration of feed scarcity. Plasma globulin concentration may increase in chronic infections caused by, for example, gastrointestinal parasites. Consequently, gastrointestinal parasites cause a significant reduction in plasma albumin concentration due to a loss of albumin from the host animal (Kaneko, 1997), reducing the albumin: globulin (A: G) ratio. A low A: G ratio may signify an increase in the blood globulin concentration caused by chronic parasitism or compensation for the albumin loss present in protein malnutrition (Payne, 1987), with higher ratios indicating a response to hyperalbuminaemia caused by dehydration. This indicates that caution is required in interpreting such circumstances, implying that other parameters, such as urea, should be considered alongside.

Urea is a nitrogenous compound synthesized in the liver and excreted through urine so as to prevent the excess nitrogen released in protein metabolism from becoming toxic and harmful to the animal (Kida *et al*., 2007). Urea production is indicative of short-term changes in protein metabolism and complements the information provided by the analysis of blood TP and albumin concentrations (Payne, 1987). A decrease in the blood urea concentration of ruminant animals has been related to low dietary intake of protein due to the recycling of urea from blood back to the rumen under low protein intake circumstances (Kaur and Arora, 1995). Blood urea nitrogen is used as a retrospective diagnostic tool to analyze change in pasture or forage on offer, or change in pasture management (Hammond, 2006) for dairy cows, beef cattle, sheep and dairy goats.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study Area

The study was conducted in Zaria, which is located in Kaduna State, in the North-Western region of Nigeria, on latitude 11° and 12° N and longitude 7° and 33° E at an altitude of 640m above sea level.

3.2 Determination of Sample Size

The sample size was calculated using the formula by Thrusfield (1995).

$N=Z^2Pq/d^2$

Where q=1-p

n=sample size

P= prevalence rate (89.1%, Ajanusi and Chiezey, 2006).

Z =desired confidence, = 1.96

d = allowable error, = 0.05

Hence, sample size for *Haemonchus contortus*

q = 1-89.1%

= 1-0.891

q = 0.109

$$n = \frac{(1.96)^2 \times 0.891 \times 0.109}{(0.0025)^2}$$

$$= \frac{0.373092}{0.0025}$$

= 149.24

That was the minimum number of samples that could be collected. However, 300 samples were collected to reduce error due to sampling.

3.3 Sample collection

A total of 300 Red Sokoto goats of various ages and both sexes from the Kano road (Dogarawa) and Samaru slaughter slabs, both in Sabon Gari LGA of Kaduna state were used for this study. Samples were obtained at intervals which involved at least two visits to the slaughter slabs per week. The simple random sampling technique was used to select the animals for sampling that is, any animal that was available was sampled. On each visit to the slaughter slabs, between five and ten samples were collected. Each animal was scored using the FAMACHA© chart, and its body condition assessed. Five ml of blood was collected from the jugular vein at the point of slaughter into screw- capped, sterile plastic sample bottles containing anticoagulant (EDTA) and another 5 ml into plain sample bottles. Fecal samples were also collected directly from the rectum of each animal into clean disposable polythene gloves before slaughter. After slaughter and evisceration, the abomasum of each selected animal was ligated at both the omaso-abomasal and abomaso-duodenal junctions with strings and then detached into a plastic container and all the three samples were labeled with the same number.

3.4 Scoring Procedure

3.4.1 Body condition scoring

Body condition score (BCS) of each goat was assessed by physically feeling the level of muscling and fat deposition over and around the vertebrae in the loin region. This was assigned on a scale of 1-5, according to Friedricks (1993), where a score of 1 indicates a thin and emaciated goat whilst a score of 5 indicates an obese goat (Table 3.1).

Table 3.1: Body condition score descriptions as used in the assessment of the goats

Score	Assessment	Observable features
1	Very poor	Deep cavity under tail and around tail head. No fatty tissue felt at loin. Pins, hooks and short ribs can be felt. Edges feel sharp
2	Poor	Cavity around the tail head is evident. No fatty tissue is felt between skin and pelvis. End of short ribs are sharp. Bones can be felt
3	Good	Slight cavity lined with fatty apparent at tail head. Area between pins not very well pronounced. End of short ribs can be felt with moderate pressure. Hooks and pins can be felt but are covered with some

		flesh.
4	Fatty	Depression between pin and tail not pronounced Pelvis felt with firm pressure Short ribs cannot be felt even with firm pressure No depression is visible between the backbone and hip bones
5	Grossly fat (obese)	Tail head buried in fatty tissue Area between pins and tailbone is rounded No part of the pelvis can be felt, even with firm pressure

Source: Friedricks (1993) for the description of body condition scores.

3.4.2 FAMACHA© Scoring

The FAMACHA©scores were determined by opening the lower eyelid of the goat prior to slaughter and comparing the color of the conjunctiva with five different scores on the chart, where 1 indicates a non - anemic goat whilst 5 indicates a severely anemic goat, as described by Kaplan *et al*. (2004).

3.4.3 Blood sample analyses

The blood samples taken with EDTA were used for hematological evaluation and screening for hemoparasites, while the samples collected without EDTA were allowed to clot at room temperature and the sera harvested for biochemical assays (Ghazei, 2006).

3.4.3.1 PCV determination

The 5 ml of blood collected into sample bottles with EDTA were transported to the Clinical Pathology Laboratory of the Department of Veterinary Pathology, Ahmadu Bello University, Zaria, for determination of PCV values using the micro-hematocrit technique described by Coles (1974). Non-heparinized capillary tubes (John Poulten Limited, England) were filled with the blood in bottles containing anticoagulant from the animals. About 15 mm of the capillary tubes were left unfilled and the open end of each of the tubes was carefully sealed with bunsen flame. The tubes were then loaded into a micro-hematocrit centrifuge machine (Hawskey, England) and centrifuged at 1000g for ten minutes. A hematocrit reader (Hawskey, England) was finally used to read the PCV value for each of the tubes.

3.4.3.2 Biochemical analyses

Sera were analyzed for total serum proteins, albumin, urea and cholesterol in the Clinical Pathology Laboratory of the Ahmadu Bello University Teaching Hospital, Shika, Zaria, using the Bayer Express plus Clinical Chemistry Autoanalyser (Bayer® Germany).

3.4.3.3 Screening for hemoparasites

Thin blood smears were made on clean glass slides and stained with Giemsa as described by Shah-Fischer and Say (1989), in the Protozoology Laboratory of the Department of Parasitology and Entomology, Faculty of Veterinary Medicine. The slides were then examined under light microscopy using oil immersion (x100 magnification) to detect the presence and level of infection with any hemoparasites.

3.4.4 Fecal Sample Analyses

Fecal egg counts were determined using the modified McMaster technique with a saturated sodium chloride / sucrose solution of specific gravity 1.28 as the flotation medium (Whitlock, 1948). Briefly, two grams of feces was suspended in 13ml of the flotation medium and centrifuged at 250rpm (11g) for 10 minutes. Well mixed aliquot of the supernatant of each sample was charged in both chambers of the McMaster slide and FEC done at x10 objective. The number of nematode eggs per gram of feces was obtained by multiplying the total number of eggs counted in the two squares of the McMaster slide by the dilution factor of 50 (Whitlock, 1948). Samples were also screened for fluke eggs by means of the sedimentation technique (Pratt, 1985) and identified using keys developed by Soulsby (1982), Uhlinger (1991) and Foreyt (2001).

3.4.5 Processing of Abomasum

Abomasal samples were processed as described by Pratt, (1985) and the Manual of Veterinary Parasitological Laboratory Techniques (M.A.F.F., 1977; Anon., 1987). Briefly, each abomasum was placed in a tray and then slit along the greater curvature over a sieve and the content washed in a fine spray of water into a 1000ml beaker. The mucosa was scrubbed thoroughly to remove any adhering worms, paying particular attention to cleaning between the folds of the mucous membrane. The abomasal content was washed several times, until all the coloring matter was removed and the residue in the sieve was clear and transparent. This was then transferred to a 500ml container, from which small aliquots were poured into a transparent plastic Petri dish and adult *Haemonchus* were counted over an illuminated Picker lamp.

3.4.6 FAMACHA© interpretation

The FAMACHA© categories and their respective PCV values were analyzed according to Bath *et al*. (2001). FAMACHA © eye scores were compared with PCV to determine the rates of false negatives and positives, trues negatives and positives, specificity and sensitivity in the sampled goats. For the calculation of the sensitivity and specificity of the FAMACHA© system, three different criteria were evaluated:

(I)Animals classified as FAMACHA© 3, 4 and 5 were considered to be anemic (positive-test) and FAMACHA© 1 and 2 non-anemic (negative test).

(II) Animals classified as FAMACHA© 4 and 5 were considered to be anemic (positive test) and FAMACHA© 1, 2and 3 non-anemic (negative test).

(III) Animals classified as FAMACHA© 5 only were considered to be anemic (positive-test) and FAMACHA© 1, 2, 3 and 4 non-anemic (negative test).

The definition of "True Positive, False Positive, False Negative and True Negative" is given below in Table 4.4.

For the PCV, the standard test used to confirm anemia, four different values were considered: ≤17; ≤18%; ≥ 18%; and ≥ 28%.The different values had to be used as no precise value for PCV has been clearly established at which anemia crosses the threshold of clinical importance (Kaplan *et al*., 2004; Burke *et al*., 2007). A true positive (TP) result was defined as animals that were anemic (PCV ≤17 or ≤18) with pale eye scores (4, 5 or 3, 4, 5 or 5). A false positive (FP) result was defined as animals that were not anemic (PCV >17, >18) with pale eye scores. A false negative (FN) result was defined as animals that were anemic (PCV≤17 or ≤18) with red or pink eye scores (1, 2 or 1, 2, 3 or 1, 2, 3, 4). A true negative (TN) result was defined as animals that were not anemic (PCV ≥28%) with pink or red eye scores. Sensitivity, and specificity, false positives and negatives, true positives and negatives were calculated according to Vatta *et al.* (2001) and Thrusfield (2005). Sensitivity (Se) is the proportion of infected or diseased

individuals with a positive test or true positive (TP), or in the case of the FAMACHA© clinical assay, the proportion of anemic animals correctly identified as anemic, [Se = TP ×100/ (TP + FN)]. Specificity (Sp) is defined as the proportion of disease-free individuals that test negative or true negative (TN), i.e. the proportion of non-anemic animals that are correctly categorized as such, [Sp = TN × 100/ (TN + FP)].

3.5 Data Analyses

Data analysis was conducted using SPSS version 15 for windows. Parameters were analyzed by one-way analysis of variance (ANOVA). Correlations between variables were analyzed by Pearson's moment correlation test for parametric data or Spearman's Rank order test for non-parametric data. Summary data were presented as mean ± standard error of the mean (SEM) and probabilities of 0.05 or less were considered significant.

CHAPTER FOUR

RESULTS

4.1 Body Condition Scores

A total of 14 (4.67%), 46 (15.33%), 76 (25.33%), 100 (33.33%) and 64 (21.33%) goats had a Body Condition Score of 1, 2, 3, 4, & 5 respectively, while a total of 38(12.67%), 83(27.67%), 107(35.67%), 50(16.67%) and 22(7.33%) had FS of 1,2,3,4 and 5 respectively (Table 4.1). The mean BCS for goats with FS of 1 was 4.82±0.0637, the range being 4-5. The corresponding values for goats with FS of 2, 3, 4 and 5 were 4.23±0.057 (range 2-5), 3.43±0.064 (range 2-5), 2.28±0.117 (range 1-5) and 1.70±0.127 (range 1-2). (Table 4.3). There was a negative correlation between BC and FS (r = -0.9937) and this was statistically significant (P<0.0001).

Table 4.1: Relationship between FAMACHA© and BCS of 300 RS goats in Zaria.

	Body Condition Scores					TOTAL
FS	**1**	**2**	**3**	**4**	**5**	
1				6	32	**38**
2		1	5	52	25	**83**
3		5	60	35	7	**107**
4	6	23	14	7		**50**
5	8	14				**22**
TOTAL	**14**	**43**	**79**	**100**	**64**	**300**

4.2 Relationship between FAMACHA© Scores and PCV

The relationship between the FAMACHA© scores (FS) and mean PCV of the sampled goats was an inverse one. Overall, values for PCV ranged from 12 to 39% for the goats. Of the goats, 119 (39.6%) had FS of 1 and 2 with mean PCV >31% and range 25-39%, while 161 (53.7%) had FS of 3 and 4 with mean PCV 26.5% and range 12-39%. Only 20 (6.6%) of the goats had a FS of 5, with a mean PCV 18% and range 7-15%. Also, 73% of goats that had FS of 1 had a PCV range of 32-39%, 49.4% and 50.6% of goats with FS of 2 had PCV range of 24-31 and 32-39%; 70% of goats with FS of 3 had a PCV range of 24-31%; 50 and 39.3% of goats with FS of 4 had PCV range of 16-23 and 24-31% respectively; while 60% of goats with FS of 5 had PCV range of 16-23%. PCV values in FS 5 were significantly lower ($P<0.05$) than PCV values for animals in other categories. There was a negative correlation between PCV and FS ($r = -0.6184$) and this was statistically significant ($P<0.0001$)

Table 4.2: Relationship between FAMACHA© Score and Packed Cell Volume in 300 Red Sokoto Goats in Zaria.

PCV RANGE	FAMACHA© SCORE					TOTAL
	1	2	3	4	5	
7-15			2	4	4	**10**
16-23			8	28	12	**48**
24-31	9	42	74	22	3	**150**
32-39	25	43	21	2	1	**92**
TOTAL	**34**	**85**	**105**	**56**	**20**	**300**

The distribution of packed cell volume, fecal egg count body condition score and adult *Haemonchus* counts are given below in table 4.3.

Table 4.3: The distribution of FAMACHA© scores and corresponding Mean (±SEM) PCV, FEC, BCS and Adult *Haemonchus* counts in 300 RSG in Zaria

FS	Frequency (%)	Mean PCV	Mean FEC	Mean WC	Mean BCS
1	38(12.67)	32.1±0.42^{a}	269.47±110.37^{a}	9.76±5.56^{a}	4.82±0.064^{a}
2	83(27.67)	31.3±0.36^{ab}	926.49±228.30^{b}	41.50±7.76^{b}	4.23±0.057^{ab}
3	107(35.67)	28.3±0.43^{b}	1757.57±240.65^{c}	119.89±14.16^{c}	3.43±0.064^{b}
4	50(16.67)	23.8±0.66^{c}	2488.50±394.04^{d}	332.54±61.67^{d}	2.28±0.117^{c}
5	22(7.33)	18.1±1.69^{d}	5923.26±2387.50^{e}	833.90±412.67^{e}	1.70±0.127^{d}

Note: Means with different superscript within the same column are significantly different.

4.3 FAMACHA© Scores, PCV and Anemia thresholds

Eye score values were compared with PCV values at different anemia criteria to determine rates of false negatives, false positives, sensitivity and specificity as defined by the parameters established for anemia and need for treatment (Table 4.4). The cut-off value for anemia in this study was considered to be PCV 18%, because the mean PCV value for the lowest FS (score 5) was 18.1% (Table 4.3).The sensitivity ranged from 41.7% to 100% and the specificity from 42.5% to 97.5% (Appendix I), depending on the criterion used (Table 4.4).

When animals with FAMACHA© scores 4 and 5 were considered as anemic at PCV ≥ 18%, 224 (74.67%) were assigned true negative, 57 (19%) were false positive, 16 (5.33%) were true positive while 3 (1%) were false negative (Table 4.4), with sensitivity and specificity of 84.2% and 79.7% respectively. When FS 4 and 5 were considered anemic at PCV ≤ 18%, sensitivity was 78.9% and specificity 80.4%, with over 50% of the results being false positives. Only 5% of the animals were true positives.

When animals with FS 3, 4 and 5 were considered anemic, 120 (40%) were assigned true negative, 162 (54%) were false positive, 18 (6%) were true positive while none was false negative (Table 4.4). Sensitivity and specificity values were 100% and 42.5% respectively.

With FS 5 considered as anemic and PCV ≤17%, specificity was very high (97.5%) but sensitivity slightly decreased to 41.7% and less than 2% of the animals would have been given an anthelmintic treatment under this category. When FS 1, 2 and 3 (PCV≥ 28%) were categorized as non-anemic, sensitivity was 73.9% and specificity 81.5%, with only 5% of the animals being false positive.

Table 4.4: Frequency and percentages of false negatives, false positives, true negatives, true positives and FAMACHA© eye scores with corresponding

PCV values using different criteria for anemia threshold.

Criteria	True positive	False positive	True negative	False negative	Sensitivity (%)	Specificity (%)
FAMACHA© eye score 3,4,5 PCV≤18	18 (6.0%)	162 (54%)	120 (40%)	0	100	42.5
FAMACHA© eye score 4,5 PCV≤18	15 (5%)	55 (18.3%)	226 (75.3%)	4 (1.3%)	78.9	80.4
FAMACHA© eye score 4,5 PCV ≥18	16 (5.3%)	57 (19%)	224(74.67%)	3(1%)	84.2	79.7
FAMACHA© eye score 1,2,3 PCV≥28	162(54%)	15(5%)	66 (22%)	57(19%)	73.9	81.5
FAMACHA© eye score 5 PCV ≤17	5(1.67%)	14 (4.7%)	274 (91.3%)	7 (2.3%)	41.7	97.5

a Sensitivity = (true positives / (true positives + false negatives) x100.

b.Specificity = (true negatives / (true negatives + false positives) x100.

4.4: Relationship between FAMACHA© Scores and Fecal Egg count of 300 RSG

The result obtained for the sampled goats showed that there was direct relationship between the FS and FEC values of the goats. Thus, goats that had the lowest mean FEC value of 269.47±110.37 had a FS of 1, while goats that had the highest mean FEC value of 5923.26±2387.50 had a FS of 5 (Table 4.3). All the mean FEC values for the different FS were significantly different from each other ($P<0.05$). Fluke eggs were found in 22 (7.3%) of the sampled goats. There was a positive correlation between FS and FEC ($r = 0.3191$) and this was statistically significant ($p< 0.0001$).

Table 4.5: Relationship between FAMACHA© Scores and Fecal Egg count in 300 Red Sokoto Goats.

FEC Range	FAMACHA© SCORE					Total
	1	2	3	4	5	
0-5000	40	80	90	51	15	276
5001-15000		1	10	7	2	20
15001-18000			1		2	3
18001-43000					1	1
Total	40	81	101	58	20	**300**

4.5: Relationship between FAMACHA© Scores and Adult *Haemonchus* counts in 300 Red Sokoto Goats.

There was an inverse relationship between mean adult *Haemonchus* counts of the goats and their FS. Thus, goats that had a mean worm count of 9.76±5.56 had a FS of 1, while goats that had the highest mean worm count of 833.90±412.67 had FS of 5 (Table 4.3). All the mean worm count values obtained for the various FS were significantly different from each other ($p<0.05$). The correlation between adult worm count and FS was positive ($r = 0.3216$) and highly significant ($P<0.0001$).

4.6. Distribution of worm burdens in the sampled population

The distribution of worm counts in the sampled population showed that majority (63.4%) of the goats had worm burdens of 0-858, with a mean of 80.7±31.7, while only a small percentage of the goats (7.3%) had very heavy worm burden (6-8305, the mean being 833±412.67).

Table 4.6: Relationship between FAMACHA© Score and Adult *Haemonchus* counts in 300 Red Sokoto goats

WC Range	FAMACHA© Score					Total
	1	2	3	4	5	
0-300	40	82	95	35	13	**261**
301-500		3	10	9	3	**22**
501-1000			2	10	4	**13**
1001-9000				2	2	**4**
Total	**40**	**81**	**104**	**53**	**22**	**300**

4.7: **Monthly distribution of Fecal Egg and adult *Haemonchus* counts in the Sampled goats.**

When the worm counts were analyzed according to the months in which the animals were slaughtered, (Table 4.7) the results showed that from November to January, mean WC were less than 10 worms per animal but increased gradually to over 100 and 400 in the months of September and August respectively. The monthly FEC values followed a similar pattern. The mean worm burdens obtained during the months of July and August were 143.74±12.35 and 411.36±42.03 respectively, which were significantly higher ($p<0.05$) than the values obtained for the months of December and January, the values being 7.95±1.07 and 6.60±1.05 respectively. Similarly, the mean FEC values recorded during the months of July and August were 2338.84±380.08 and 3547.77±409.12 respectively, which were also significantly higher ($p<0.05$) than the values obtained for the months of December and January, the values being 135.45±63.24 and 109.00±32.02 respectively.

Table 4.7: *Haemonchus* and FEC monthly dynamics as determined from animals Slaughtered in the two slaughter slabs over a period of 7 months.

Month	N	Mean WC	Mean FEC
July	50	143.74±12.35	2338.84±380.08
August	95	411.36±42.03	3547.77±409.12
September	53	114.19±112.23	581.88±121.26
October	40	82.80±7.03	579.50±220.65
November	20	9.45±2.01	125.50±87.32
December	22	7.95±1.07	135.45±63.24
January	20	6.60±1.05	109.00±32.02

When FAMACHA© categories were grouped as 1 and 2; 3; 4 and 5 their PCV, WC and FEC values are shown in Table 4.8. Mean PCV, WC and EPG differed significantly between the categories ($P<0.05$).

Table 4.8: Relationships between Grouped FAMACHA© scores, Ranges of PCV and some Parasitological Indicators in 300 RS Goats.

	FS Mode	N	Mean FEC	Mean WC	Mean PCV
PCV≥32, FS 1&2	2	93	654.36[a]	27.54[a]	33.26[a]
PCV27-29, FS 3	-	38	1388.16[b]	140.76[b]	25.95[b]
PCV≤19, FS 4&5	4	46	3397.34[c]	583.89[c]	19.5[c]

Note: Means with different superscripts within the same column are significantly different ($p<0.05$).

4.8 Haemoparasites

No haemoparasites were seen in the thin blood smears examined in this study.

4.9 Ectoparasites

Out of the 300 goats studied, 48 (16%) were infested with lice, out of which 6 animals had lice infestation as a primary infection (with worm counts less than 100) and PCV <18%.

4.10 Blood Metabolites

Table 4.9 shows the relationship between different FS and mean ± SEM concentrations of Urea, TP, Albumin and Cholesterol of the 300 RS goats studied. All the four blood metabolites in consideration did not show any significant variation ($p<0.05$) between the 5 different FS. The result also showed that the values for all the four blood metabolites corresponding to the 5 FS were within the normal range for RS goats (Tambuwal *et al.*, 2002). Again, in Table 4.10, the relationships between different ranges of PCV and the mean values for the different blood metabolites is shown. The result follows a similar pattern as that in Table 4.9., the mean values for the different blood metabolites corresponding to the different ranges of FS did not show any significant variation and were within the normal range for the species.

Table 4.9: Relationships between different FS and Mean ±SEM of some Blood Metabolites in 300 RS Goats.

FS	Frequency	Mean Urea (mmol/l)	Mean TP (g/100ml)	Mean Albumin(g/100ml)	Mean Cholesterol(mg/dl)
1	38	4.5±2.1	4.4±1.6	2.5±1.8	89±0.08^{ab}
2	83	4.6±2.7	4.6±1.4	2.4±1.7	90±0.05^{a}
3	107	4.7±1.9	4.8±1.5	2.7±1.3	88±0.08^{ab}
4	50	4.6±2.0	4.5±1.5	2.6±1.5	88±0.73^{ab}
5	22	4.7±2.2	4.7±1.8	2.5±1.7	90±0.09^{a}

Note: Means with different superscripts within the same column are significantly different ($p<0.05$).

When FAMACHA© categories were grouped as 1 and 2; 3; 4 and 5 their PCV and blood metabolites values are shown in Table 4.10.There was no significant difference between the Means of the various categories ($P<0.05$).

Table 4.10: Relationships between grouped PCV, FS and some Blood Metabolites in 300 RS Goats.

	N	Mean Urea (mmol/l)	Mean TP (g/100ml)	Mean Albumin (g/100ml)	Mean Cholesterol (mg/dl)
PCV≥32, FS 1&2	93	4.7±2.1	4.4±1.8	2.5±1.6	90±5.21
PCV 27-29, FS 3	38	4.5±1.9	4.5±1.6	2.4±1.4	89±6.34
PCV ≤19, FS4&5	46	4.6±2.1	4.4±1.7	2.4±1.6	90±5.42

CHAPTER FIVE

DISCUSSION

The present study provides preliminary evaluation on the possible use of FAMACHA© as a tool to identify and select animals that need anthelmintic treatment against haemonchosis, as has been shown in other evaluation studies in goats (Vatta *et al*., 2001; Kaplan *et al*., 2004; Burke *et al*., 2007a,). Sensitivity obtained ranged from 41.7% to 100% and the specificity from 42.5% to 97.5%, depending on the criteria used.

Higher sensitivity values are more important than higher specificity values in the FAMACHA© system (Vatta *et al*., 2001).

Not treating the animals that are truly in need of treatment (false negatives) exposes them to the risk of death, while treating animals that do not need treatment (false positives) does not cause serious problems (Vatta *et al*., 2001; Kaplan *et al*., 2004). In this respect the high percentage of true negatives (74.67%) obtained in this study (animals with FAMACHA© scores 1, 2 or 3 and a PCV >18%) suggests the usefulness of the FAMACHA© system in making correct decisions for selective treatment. This is in agreement with the findings of Sangster (1999) and Van Wyk (2001). All those animals that were classified as true negatives in this study would have been treated with anthelmintics under the common "treat all" practice. That would amount to an unnecessary treatment, increasing the farmer's expenses and also reducing the percentage of refugia. This ultimately results in increasing the chances for the development of anthelmintic resistance (Vatta *et al.*, 2001; Susan, 2009).

In this study, a PCV cut - off of ≤18% was used as critical value for necessitating treatment, and all animals scored 4 and 5 were considered as anemic. This is the criterion that has been adopted as a model for assessing the usefulness of the FAMACHA© system in this study. Using these criteria, the percentage of false negatives (animals that had a PCV ≤18% but were scored as 1, 2 or 3 i.e. undetected anemic animals) was only 1%. This refers to the percentage of

animals that would be erroneously skipped during anthelmintic administration because, based on their FS, they are assumed to be non-anemic. Other physiological and / or pathological factors could result in an increased redness of the eye and so affect the accuracy of the FAMACHA© system. Such factors include dusty and hot conditions, driving animals a long way without rest, fever and infectious eye diseases (Vatta and Krecek, 2001). All these factors could lead to animals being erroneously classified as false negatives.

The relatively high percentage of false positives (19%) (False positives refer to the percentage of animals that are not anemic but would nevertheless have been treated with anthelmintic because their FS indicate that they are anemic) recorded in this study is similar to what has been reported in previous studies (Kaplan *et al*., 2004; Glaji *et al*., 2008). Based on this result, it may be tempting to consider this as evidence that the test is not an accurate method for selecting animals for treatment; however, Kaplan *et al.* (2004) explained that such a conclusion would be a serious mistake since, as pointed above, using the traditional "treat all animals" approach and applying the same criteria for measuring false positivity would have resulted in much higher false positives and also much higher costs of treatments.

The finding of true positives to be 5.33% showed the usefulness of the FAMACHA© system in detecting animals in need of treatment with anthelmintic. Based on this result, those were the only animals that would actually need treatment against GIT parasites. Again, compared to the traditional "treat all" approach, this system is most desirable for control of anthelmintic resistance and selection of animals that are resilient to *H.contortus* and probably other GI parasites (Kaplan, 2005).

The high negative correlations between body condition scores and FS of the sampled goats showed that the lower the FS, the higher the corresponding body condition score.

This finding suggests that the anemic status of an animal which is described by the FS and PCV is also highly related to the level of *Haemonchus* infestations and nutritional status of the

animal. It is known that nutrition is a key factor in the development of immunity and resilience to gastrointestinal nematodes(Kyriazakis and Houdjk, 2005; Knox *et al*., 2006).

In this study goats with higher worm burdens and EPG also had low Packed Cell Volume and high FS, which strongly suggests that worm burdens were the main contributory factor to anemia. This is in agreement with earlier results obtained for Barbari and Jamunapari kids in Pakistan by Chauhan *et al*.(2003), and Coop and Kyriazakis (2001). Even though goats are usually co-infected by several species of GI nematodes; *H.contortus* is the most prevalent of small ruminant trichostrongylids (Dorny *et al*., 1996). Daily blood loss caused by single adult *Haemonchus* has been estimated to be 0.05ml. Also, female *H.contortus* has been reported to be highly fecund, with a single female releasing between 5000 to 10,000 eggs in the feces daily (Souslby,1982; Dorny *et al*., 1996). These factors explain the high positive correlation between FS and FEC that was observed in this study.

Greater worm burdens occurred in the wet season due to favorable conditions of humidity and temperature on pasture for nematode larval survival. This finding agrees with the reports of Regassa *et al*.(2006) and Mbuh *et al*.(2008). The implication is that the animals need to be scored during this season.This indicates that tactical anthelmintic treatments during the wet season would be useful strategies for the control of *H. contortus* in indigenous goats raised semi extensively in the study area. If untreated, this may eventually result in anemia, loss of body weight and condition.

The finding of fluke eggs in only 22 (7.3%) of the animals selected in this study might be due to the fact that in majority of cases, small ruminants die during the acute phase of fasciolosis (Administrator, 2007); or that fasciolosis is not a major problem in goats in the study area. Goats are generally not herded with sheep and cattle. Furthermore, the preferred browsing behavior of goats decreases their chances of coming in contact with the infective stages (Sissay, 2006). Nonetheless, the low prevalence observed in this study indicates that flukes

may not be considered a major contributory factor to anemia in goats in the study area. Likewise, other helminths such as Strongyloides and Moneizia whose eggs were observed in this study are non-haematophagous, and therefore do not affect PCV values but may affect body condition. The fact that no haemoparasites were discovered in the thin blood smears examined in this study could be due to the low prevalence in the study area. Ajanusi and Chiezey (2006) conducted a one-year study on the prevalence of hemoparasites in goats in the study area and reported that only 9.2% of the animals studied were infected with *Anaplasma ovis*, while 3% had *Theileria ovis*. The present study was conducted for less than a year. This low prevalence suggests that hemoparasites may not be considered as important contributory causes of anemia in goats in the study area.

The presence of lice in 16% of the animals studied showed that these ectoparasites could serve as important contributory causes of anemia in goats. It was importantly discovered that some of the animals (2%) that had high FS, but low adult *Haemonchus* burdens had heavy lice infestation. Lice are known to feed on the host's blood (Ballweber, 2001).. This implies that in farms without adequate ectoparasite control it may be a source of anemia in goats and so animals may continue to do poorly in spite of anthelmintic treatments if ectoparasite control is not adequate. Obviously, farmers should continue to be vigilant for other indicators of ill health such as lethargy and poor body condition.

The finding of blood urea levels within the normal range (Tambuwal *et al*., 2002) suggests that nutritional levels of the animals were adequate. Persistent hypoglycemia and protein deficiency would normally result in increased catabolic activity for gluconeogenesis, thus giving rise to higher serum urea levels (Radostits *et al*. 2000). Thus this result suggests that goats raised under the traditional semi - extensive system seem to receive adequate nutrition and this may have contributed to their low worm burdens. Nutrition is known to be a key factor in the development of resistance and resilience to gastrointestinal parasites(Kyriazakis and

Houdjk, 2005; Knox *et al*., 2006). The normal serum protein and cholesterol values obtained also confirm that animals were in good body condition.

The fact that values obtained for serum proteins and cholesterol in this study were not significantly different from normal reference values could also be attributed to the low levels of infections found.

Overall, this study has established that the FAMACHA© system is a useful tool for identifying Red Sokoto goats that need treatment against haemonchosis.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From this study, it has been established that the FAMACHA© system is a useful tool that small ruminant producers could use to identify > 70% of animals that do not need anthelmintic treatment in a flock. This is in contrast to the blanket treatment of all animals, and would thereby save dewormer costs and contributing to more worms in refugia. Worms are usually over dispersed among animals in a flock (Hoste *et al.* 2001), with a relatively small number of animals infected with most of the worms. Furthermore, within a flock, it tends to be the same animals that are consistently infected with high worm burdens over time. If the FAMACHA© system is used correctly and consistently in a flock, such highly susceptible animals could be easily identified and treated to reduce their contamination of pasture for the rest of the flock. Over time, this practice would help in the selection and buildup of resilient animals.

6.2 Recommendation

1. There is the need for further studies using live animals that can be scored more frequently with the FAMACHA© cards.

2. There is the need for experimental infection of goats with *Haemonchus* in the absence of other possible causes of anemia so as to carry out a more detailed study on the accuracy of the FAMACHA© System.

3. Based on this result, Red Sokoto goats scored 1, 2 or 3 with the FAMACHA© chart can be considered non-anemic and not in need of deworming, while those in categories 4 and 5 are in need of deworming.

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APPENDIX I: Working formula for determination of sensitivity and specificity of the FAMACHA© system.

When FAMACHA scores 4 and 5 are considered anemic at PCV ≥ 18%,

Sensitivity = true positives / (true positives + false negatives) x 100.

Substituting,

= 16/16+3 x100

= 16/19 x 100

= **84.2 %**

Specificity = true negatives / (true negatives + false positives) x 100.

Substituting,

= 224/ 224 + 57 x 100

=224/281 x 100

= **79.7 %**

APPENDIX II: Working formula for the determination of egg per gram (EPG) of Fecal samples.

2 g of feces suspended in 13 ml of flotation medium (saturated NaCl / sucrose solution, specific gravity of 1.28).

NOTE: a) 1g ≡ 1 ml ≡1cm^3

b). 1 McMaster chamber = 0.15ml, 2 chambers = 0.15 x 2 = 0.3ml.

2g of feces + 13ml of flotation medium = 15ml (total volume).

If x eggs is contained in 0.3ml (McMaster chambers)

It follows that 15ml will contain (15x eggs X 1/0.3) = 50x eggs

Hence, 50 is the multiplication factor for Fecal Egg Count (FEC) in this study.

Egg per Gram (EPG) is given by FEC x 50 (McMaster egg count).