

Full Length Research Paper

Changes in the serum profiles of lipids and cholesterol in sheep experimental model of acute African trypanosomosis

Sani Adamu^{1*}, Abiodun A. Ige¹, Isa D. Jatau², Joel S. Neils³, Nicodemus M. Useh¹, Mohammed Bisalla¹, Najume D.G. Ibrahim¹, Andrew J. Nok⁴ and King A. N. Esievo¹

¹Department of Veterinary Pathology and Microbiology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria.

²Department of Veterinary Parasitology and Entomology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria.

³Department of Animal Production, Adamawa State University, Mubi, Adamawa State, Nigeria.

⁴Department of Biochemistry, Faculty of Science, Ahmadu Bello University, Zaria, Nigeria.

Accepted 2 April, 2008

In an effort to further elucidate the possible effect of trypanosome infection on serum levels of some lipids and cholesterol, five sheep (the infected group) were each intravenously inoculated with 2 ml of blood containing 1×10^5 *Trypanosoma congolense* organisms. Another five uninfected sheep served as control group. Blood samples were collected from all the animals every other day from the day of infection (day 0) up to the termination of the experiment. The samples were used for haematological and parasitological analyses and determination of serum concentrations of total cholesterol, triglycerides, high density lipoprotein-cholesterol (HDL-cholesterol) and low density lipoprotein-cholesterol (LDL-cholesterol). All animals in the infected group showed parasitaemia by day 11 post-infection (PI) and the infection caused a gradual decline in the values of packed cell volume (PCV) and those of serum total cholesterol, triglycerides, HDL-cholesterol and LDL-cholesterol. Values of all these parameters in the control group remained fairly normal, relative to the pre-infection ones on day 0, throughout the experimental period. The PI mean values of serum total cholesterol, triglycerides, HDL-cholesterol and LDL-cholesterol, measured in mmol/l, in the infected group were 3.44 ± 0.71 , 1.62 ± 0.40 , 0.78 ± 0.20 and 1.92 ± 0.40 , respectively, while those in the control group were 4.32 ± 0.18 , 2.24 ± 0.11 , 1.15 ± 0.10 and 2.26 ± 0.30 , respectively. The differences between the PI mean values in the two groups of animals were significant ($P < 0.05$). *T. congolense* utilization of the molecules could, among other factors, be the cause of the reduced serum levels of these parameters and this could be a contributory factor in the pathophysiology of some of the disorders observed in trypanosome-infected animals.

Key words: Trypanosomosis, sheep, cholesterol, triglycerides, low density lipoprotein, high density lipoprotein.

INTRODUCTION

Trypanosomosis (trypanosomiasis), a disease caused in domestic and wild animals as well as humans by tsetse fly-borne protozoan parasites belonging to the genus *Trypanosoma*, remains a serious set back to improved

and profitable livestock and mixed-crop livestock farming in tropical Africa (Kristjanson et al., 1999; Swallow, 2002; Irungu et al., 2002; Shamaki et al., 2002). In animals, the characteristic clinical features of the disease, which is also referred to as African Animal Trypanosomosis or Nagana, include intermittent fever, anaemia, anorexia, poor hair coat, emaciation, lethargy, enlarged lymph nodes, abortion, infertility decreased milk yield, sub-mandibular oedema, ascites and ocular discharge and

*Corresponding author. E-mail: sanad1966@yahoo.co.uk. Tel: +2348055696488.

mortality (Ikede and Losos; 1972; Shamaki et al., 2002). The most pathogenic trypanosome species responsible for the disease in domestic livestock are *Trypanosoma vivax* (*T. vivax*), *Trypanosoma congolense* and *Trypanosoma brucei* in cattle, sheep and goats, and *Trypanosoma simiae* in pigs (Nantulya, 1990). In humans, two major trypanosome species have been incriminated in the pathogenesis of the disease that is commonly known as Human African Trypanosomiasis or sleeping sickness; namely, *T. brucei rhodesiense* and *T. brucei gambiense* (Greenwood and Whittle, 1980; Molyneux et al., 1996; Smith et al., 1998; Dumas et al., 1999). The clinical signs of human African trypanosomiasis are intermittent fever, headache, joint pain, malaise, anaemia and, in more advanced stages of the disease, varied neurological symptoms (Darsaud et al., 2003).

Resurgence of both human African and African animal trypanosomiasis has in recent times raised concern in most African countries (Gibbons, 1992; Seed, 2001; FAO, 2002). Indeed, Seed (2001) described trypanosomiasis as truly a re-emerging infectious disease. The new trend in the epidemiology of the diseases has largely been attributed to lackadaisical attitude of the successive governments towards implementing effective surveillance and control measures aimed at curbing the devastating effects of the disease (Daniel et al., 1993; Airauchi et al., 2001; Halid, 2001; Odoya et al., 2003). African animal trypanosomiasis continues to decimate livestock population unabated even as the very low average animal protein intake of the populace (Tewe, 1999) places the obligation to improve livestock production, generally, in the continent. FAO (2002) reported that over 45 million cattle and millions of other livestock species are under the risk of coming down with the disease, while huge sums of money are being expended in the prophylactic and curative management of the disease. Information on the epidemiology of human African trypanosomiasis does not differ much from that on African animal trypanosomiasis. About 50-60 million African residents have been reported to be at risk of being infected and, according to World Health Organization, human African trypanosomiasis or sleeping sickness is still among the infectious leading killers (Gibbons, 1992; FAO, 2002). Consequently, the negative socio-economic impact of trypanosomiasis in the African continent is quite tremendous.

Numerous disorders have been reported occurring consequent to trypanosome infection in animals (Esiebo and Saror, 1991; Logan-Henfrey et al., 1992; Adamu et al., 2007). Research efforts made to elucidate the mechanisms of development of these disorders in affected animals have culminated in varying reports. Whereas some reports have provided convincing explanations on the pathophysiology of some of these disorders, others are conflicting, one of the possible reasons for which the pathogenesis of trypanosomiasis has remained incompletely understood (Rhind et al., 1997). One of such latter reports is the one on the effects of trypanosome infection on serum lipids. For example, while Nakamura (1998) re-

ported increase in the plasma levels of cholesterol and all lipid forms, except HDL-cholesterol, which occurred sequel to *T. brucei* infection in rabbits, Biryomumaisho et al. (2003) reported a decrease in plasma levels of these parameters following infection of goats with *T. congolense* and *T. brucei*.

Lipids play an important role in the body; they serve as hormones or hormone precursors, aid in digestion, provide energy, storage and metabolic fuels, act as functional and structural components in biomembranes and form insulation to allow nerve conduction and prevent heat loss (Anonymous, 2006). Consequently, any significant alteration in their plasma levels could lead to a variety of clinical disorders in the affected animals. Comparative studies carried out on trypanotolerant and trypanosusceptible groups of cattle indicated that plasma lipids might play a role in trypanotolerance (Katunguka-Rwakashaya et al., 1995; Ogunsanmi et al., 2000). There is, therefore, the need to have a clearer picture of the disease, trypanosomiasis, vis-à-vis the serum profile of lipids and cholesterol as the changes trypanosome infection could induce on the serum levels of these molecules may represent some of the pathophysiological mechanisms of development of the disease.

Works carried out by Biryomumaisho et al. (2003) and Nakamura (1998) were based on weekly blood sampling for biochemical analyses. The long interval of sampling for the analysis in these works might be partly responsible for the discordant research findings, since many serum biochemical changes reported to be consequents of trypanosome infection in animals concurred with waves of parasitaemia (Esiebo et al., 1982; Nok and Balogun, 2003; Neils et al., 2007). It is only imperative to carry out more detailed studies so that more definite and conclusive statements could be made on the possible effects of the trypanosome infection on the serum levels of lipids and cholesterol and, possibly, on the pathophysiology of some reported disorders in trypanosome-infected animals.

This study was designed to further unravel the possible effects experimental *T. congolense* infection on the serum levels of triglycerides, HDL-cholesterol and LDL-cholesterol and cholesterol in sheep.

MATERIALS AND METHODS

Experimental animals

Ten normal healthy Yankasa sheep aged between 1½ to 2 years were purchased from Seme, an apparently tsetse free zone, in Katsina State of the Nigerian Sudan Guinea Savannah. These animals were on arrival housed in fly proof animal pens. They were dewormed, using ALBENDAZOLE (Tuyil Pharm. Ind. Ltd., Nigeria) at 25 mg per kg body weight, administered orally, and injected, intramuscularly, with Oxytetracycline long acting at a dose rate of 20 mg per kg body weight. The animals were also treated against external parasites using Diazinon (DIAZINTOL®, Animal Care, Nig. Ltd.) at a concentration of 2 mL per litre of water (162 mg/mL concentration). Each of the sheep was ear-tagged to ensure proper identification.

The sheep were screened, on a weekly basis, of haemoparasites during the acclimatization period that lasted two months and just before the commencement of the experiment to certify that they were free of any parasites that could frustrate the experiment. During this period, the animals were adequately fed groundnut hay, corn bran, cowpea haulms and fresh pasture. Water was provided *ad libitum*. Physical examination and determination of body weight and rectal temperature were carried out on all the animals on a regular basis; blood samples were also collected on a routine basis, all in an effort to make the animals accustomed to the procedures that they would be subjected to during the experiment.

The infecting trypanosome organism

The *T. congolense* used in this study was obtained from Nigerian Institute of Trypanosomiasis Research at Vom in Plateau State of Northern Nigeria. The parasite was initially isolated from a pregnant cow in Karu village in Nasarawa State of Nigeria. The trypanosome stabilate was inoculated into two Sprague Dawley rats; one intraperitoneally and the other subcutaneously, and transported to the Faculty of Veterinary Medicine of Ahmadu Bello University, Zaria in Kaduna State of Nigeria, where the experiment was carried out. Two Sprague Dawley rats were separately inoculated intraperitoneally and subcutaneously, respectively, in order to insure against possible failure in the establishment of the infection in the rats.

Inoculation of donor sheep

On arrival at Zaria, blood samples were collected from these rats everyday to monitor the development of parasitaemia using the method described by Woo (1969). Parasitaemia was first detected in the rat that was inoculated intraperitoneally on day 3 PI. At peak parasitaemia on day 4 post-infection (PI) (whence parasitaemia was at swarming level), this rat was put on chloroform anaesthesia. Its jugular veins were then severed in order to collect sufficient blood into a container. This blood, which was anticoagulated with heparin, was then inoculated into a donor sheep through jugular venipuncture. Blood sample was collected everyday from this donor sheep for parasite detection using the method of Woo (1969). Parasitaemia level was determined using the modified method of Paris et al. (1982) as described by Mutayoba et al. (1994). By day 11 PI, the parasites were detectable in the donor sheep.

Grouping of animals and infection with *T. congolense* organisms

On the day parasitaemia was at its peak level (5×10^5 trypanosomes/mL of blood) in the donor sheep, the ten sheep were allocated on the basis of body weight (mean body weights, control group = 18.8 ± 0.2 kg; Infected group = 18.4 ± 0.6 kg) to two groups. The first group of animals, which was also referred to as infected group, comprised 5 sheep that were to be infected with *T. congolense*. The second group, called the control group, also had the same number of animals as the first group and served as the uninfected control. Two millilitres of blood, which contained 1×10^5 trypanosomes/ml, was collected from the donor sheep and injected into each animal in the infected group through the jugular vein. This day was, thus, tagged day 0 of infection in the experiment. Since then, the animals were closely observed for changes in demeanor and body condition.

Blood sampling for haematological and parasitological analyses

Beginning from day 0 of infection and throughout the experimental

period that lasted for 48 days, 1 mL of blood sample was collected every day from each of the animals in both the infected and control groups into a vacutainer containing ethylenediaminetetraacetic acid as an anticoagulant. This blood was used for detection and estimation of parasitaemia level in the infected group and estimation of PCV in two groups of animals. While estimation of parasitaemia was done on a daily basis in the infected group, that of PCV was carried out twice in a week up to the termination of the experiment.

Blood sampling for determination of serum lipids and cholesterol profiles

Beginning from day 0 and up day 48 PI, 4 ml of blood sample was collected from each animal in the two groups every other day into sterile screw-capped test tube containing no anticoagulant. This blood was allowed to clot and, after some hours, the serum was removed and dispensed into properly labelled sterile vials and stored at -20°C for serum triglycerides, HDL-cholesterol LDL-cholesterol and cholesterol assay.

Determination of total cholesterol, triglycerides, HDL-cholesterol and LDL-cholesterol

The determination of serum levels of cholesterol was carried out using colorimetric enzymatic end point method. Serum triglycerides were analyzed using colorimetric method after enzymatic hydrolysis with lipases. HDL-cholesterol was determined using precipitant method. All these analyses were carried out using standard commercial test kits (RANDOX Laboratories Ltd., Ardmore, Diamond Road, Cruclin, Co. Antrim, United Kingdom), following strictly the instructions provided by the manufacturers. LDL-cholesterol measured in mmol/l, was calculated from the values total cholesterol, triglycerides and HDL-cholesterol using the formula described by Friedewald et al. (1972) below:

$$\text{LDL-Chol} = \text{Total CHOL} - \text{TRIGS}/2.2 - \text{HDL-Chol}$$

Statistical analysis

Data obtained from the animals in the two experimental groups were compared statistically using Student's t-test (Steel and Torie, 1980).

RESULTS

Clinical observations

The parasites, *T. congolense* organisms, were first detected in 2 animals in the infected group on day 8 PI and by day 11, all the animals in the infected group were showing parasitaemia. Peak parasitaemia level of 5×10^5 trypanosomes per millilitre of blood was recorded on day 23 PI. Following the development of parasitaemia, all animals in the infected group came down with clinical trypanosomosis. The first clinically observed manifestations of the disease in these animals were fluctuating pyrexia ($104 - 108^\circ\text{F}$), weakness, dullness, reduced feed intake and rough hair coat. As the infection progressed, mucous membranes became pale and superficial lymph nodes were enlarged. There was a rapid decrease in

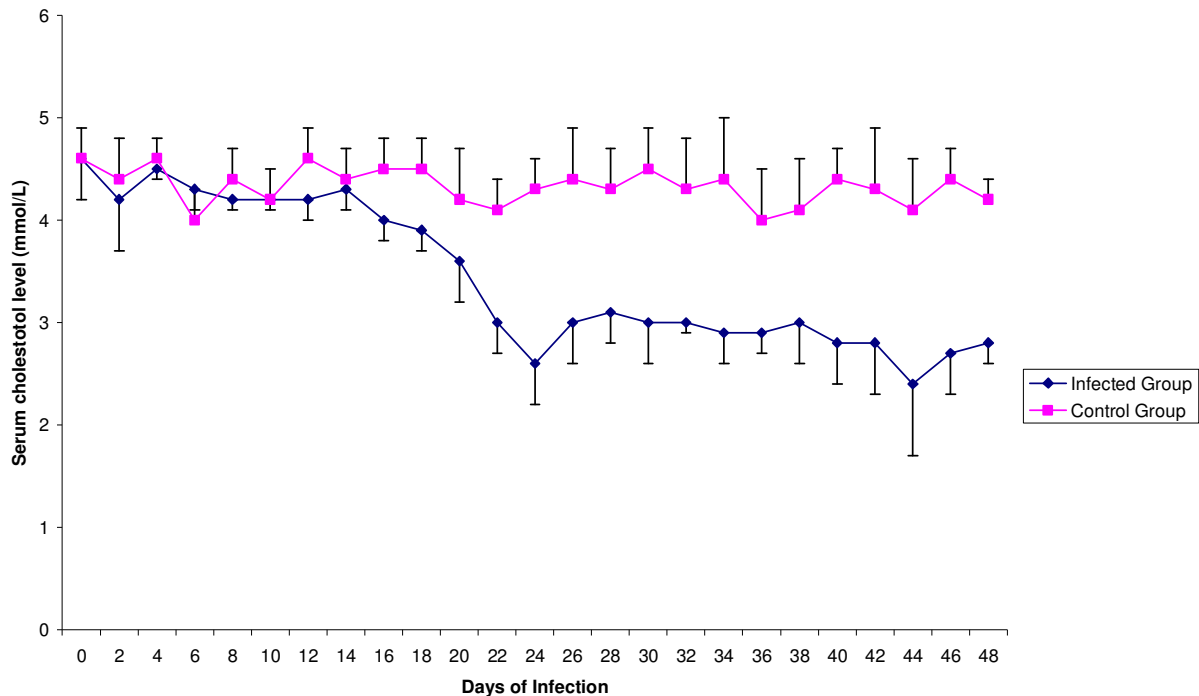


Figure 1. Mean total serum cholesterol levels in *T. congolense*-infected and control sheep.

PCV values of animals in the infected group to the extent that the mean value of this parameter dropped from the initial mean of $32.6 \pm 3.4\%$ on day 0 of infection to $23.6 \pm 4.2\%$ on day 18 PI. Minimum mean PCV value of $18.4 \pm 3.9\%$ was recorded on day 37 of infection in the infected group. PCV values in the control group remained more or less the same, with only minor fluctuations (31.4 ± 3.4 to $33.8 \pm 4.0\%$), throughout the experimental period.

Serum biochemical changes

T. congolense infection caused significant decreases in the serum values of total cholesterol triglycerides, HDL-cholesterol and LDL-cholesterol in all the animals in the infected group (Figures 1 - 4).

Decrease in mean value of total serum cholesterol was noticeable in the infected group from day 18 PI, which continued up to day 24 PI to reach a minimum value of 2.6 ± 0.4 mmol/l (Figure 1). Thereafter, the value increased to a highest value of 3.1 ± 0.3 mmol/l on day 28 PI. The mean value remained more or less at this level up to day 48 whence the experiment was terminated (Figure 1). The mean PI value (3.44 ± 0.71 mmol/l) of total serum cholesterol was significantly ($P < 0.05$) lower in the infected group than that (4.32 ± 0.18 mmol/l) in the control group. Mean serum concentration of total cholesterol in the control group remained fairly at the same level during the experiment, except for the minor fluctuations observed (Figure 1).

Decrease in mean value of serum triglycerides was

discernible as early as day 6 PI. Lowest values of this parameter were recorded on days 34 and 36 PI. This was followed by a gradual increase to reach the highest value of 2.0 ± 0.3 mmol/l on day 46 PI. Mean serum values of this parameter in the control group remained fairly the same throughout the experimental period relative to the pre-infection value on day 0 of infection with only minor fluctuations (Figure 2). The mean PI value of the serum triglycerides (1.62 ± 0.4 mmol/l) in the infected group was significantly ($P < 0.05$) lower when compared with that (2.24 ± 0.11 mmol/l) in the control group.

A pattern of decrease similar to that of cholesterol was observed in the levels of HDL-cholesterol in the infected group (Figure 3). Decrease in the HDL-cholesterol mean serum level was observed on day 8 PI, which progressed to reach lowest values on days 32 and 34 PI. This decrease was then followed by a staggering increase in the mean serum level to reach values comparable with those of the control group. The PI mean value (0.78 ± 0.2 mmol/l) of this parameter was significantly ($P < 0.05$) lower than the mean value (1.15 ± 0.1 mmol/l) in the controls. Although fluctuations in the mean serum HDL-cholesterol level were noticeable in the control sheep, there was no significant difference ($P > 0.05$) between the pre-infection and PI values.

Mean serum values of LDL-cholesterol in the infected group were comparable to those in the control group up to day 20 PI (Figure 4). Decrease in serum LDL-cholesterol concentration to a lowest level was recorded on day 22 PI (Figure 4). This was followed by an increase in the mean serum concentration to values comparable to

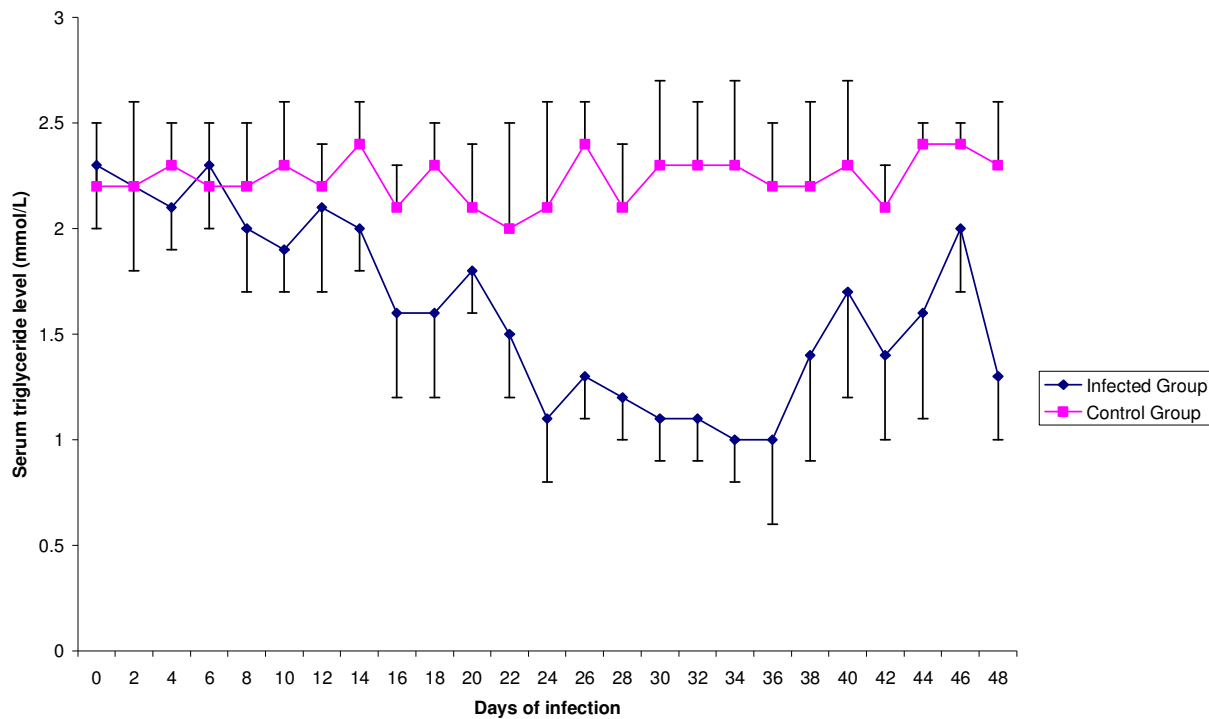


Figure 2. Mean serum triglyceride levels in *T. congolense*-infected and control sheep

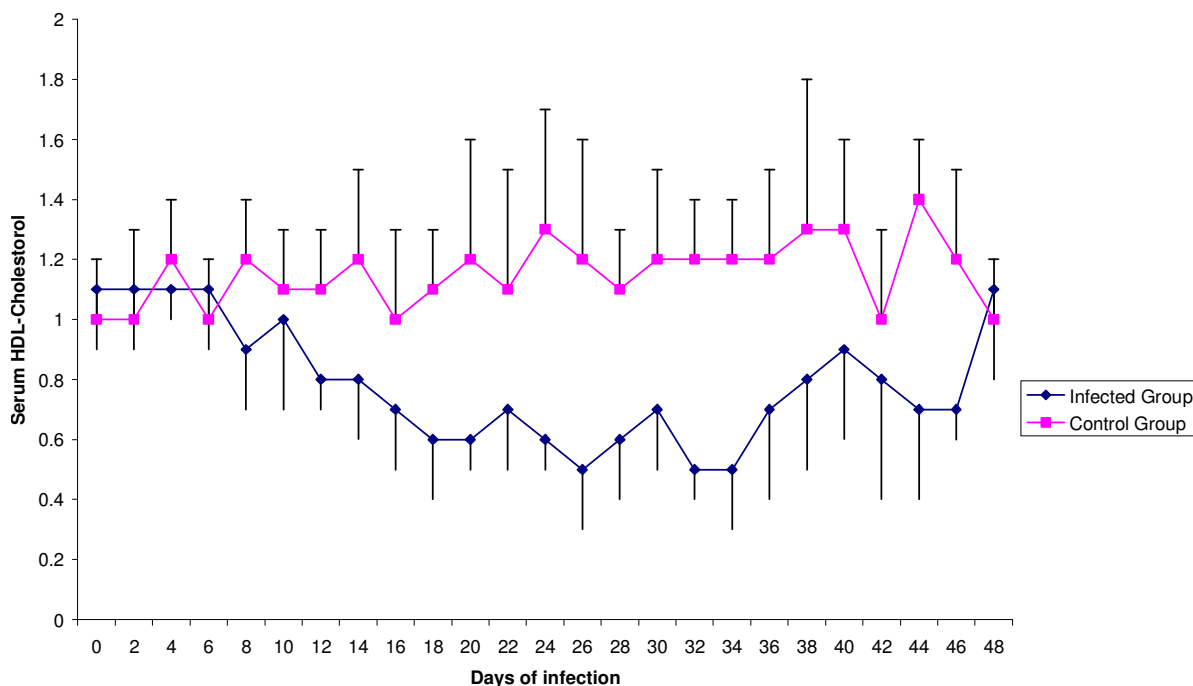


Figure 3. Mean serum levels of High Density Lipoprotein cholesterol (HDL-cholesterol) levels in *T. congolense*-infected and control sheep.

those of the control group and remained fairly so up to day 36 PI. The difference between the mean serum values (infected, 1.92 ± 0.4 mmol/l; control, 2.24 ± 0.3

mmol/l) of LDL-cholesterol in the two groups of experimental animals was statistically significant ($P < 0.05$).

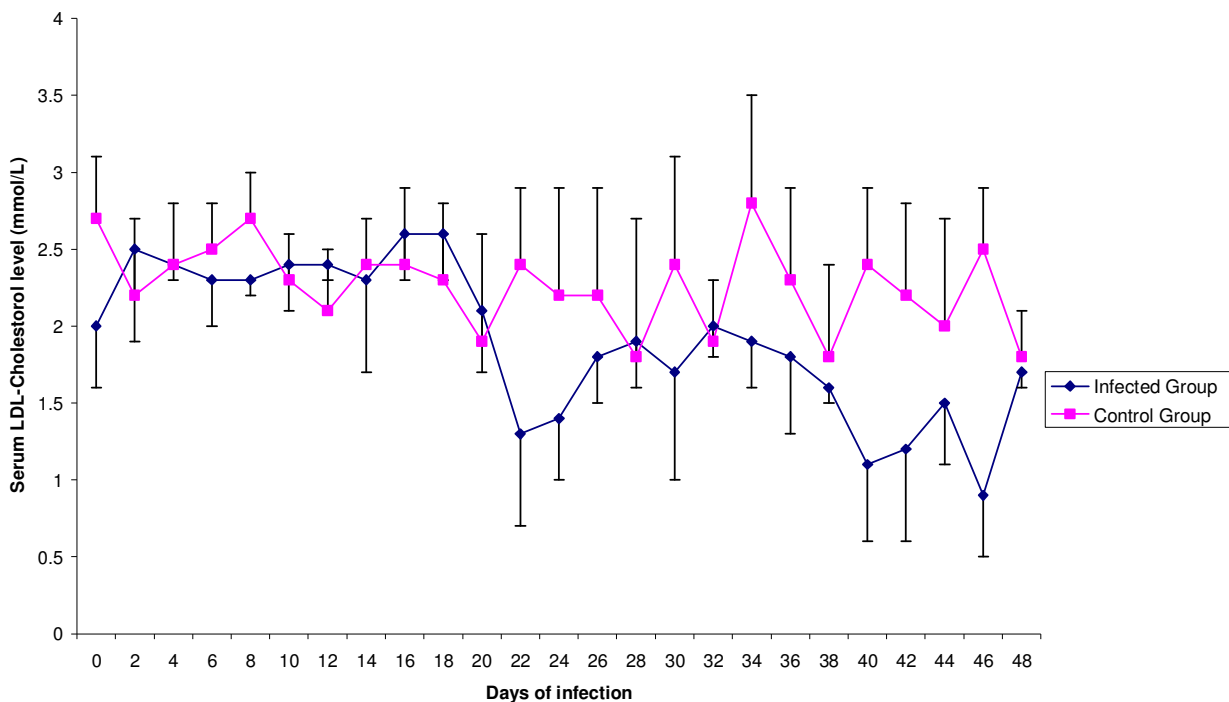


Figure 4. Mean serum levels of low density lipoprotein cholesterol (LDL-cholesterol) levels in *T. congolense*-infected and control sheep.

DISCUSSION

Findings made in the present study clearly indicate that *T. congolense* infection of sheep results in lowered values of serum HDL-cholesterol LDL-cholesterol and total cholesterol, thus, corroborating the earlier findings made by Biryomumaisho et al. (2003) in *T. congolense*- and *T. brucei*-infected Small East Africa goats. The present reports are also in conformity with those of Welde et al. (1989) and Katunguka-Rwakishaya et al. (1992) in *T. rhodesiense* infection of cattle and *T. congolense* infection of sheep, respectively. The present findings, however, contradict those made by Nakamura (1998) in *T. brucei* infection of rabbits. The present observations are also in complete deviance from those made much earlier by Diehl and Risby (1974) and Rouzer and Cerami (1980) in *T. gambiense*- and *T. brucei*-infected rabbits, respectively. The differences in either the species of trypanosomes or of the host animals used in the previous studies might have contributed to the variable results obtained. Nevertheless, it could be inferred that trypanosome infection causes a fall in serum levels of lipids and total cholesterol, at least, in sheep. Regard-less of the species of host animals and the parasite species involved, it is known that trypanosomes inflict similar disorders, except for the differences in their pathogenicity and, of course, the severity of the disease they cause in host animals (Logan-Henfrey et al., 1992).

Many pathophysiological mechanisms might have been

involved in the lowering of serum levels of triglycerides, HDL-cholesterol LDL-cholesterol and cholesterol in the trypanosome-infected animals in the present study. For example, it has been shown that lipoprotein requirements of trypanosomes are dependent upon serum LDL-cholesterol and HDL-cholesterol in order for the parasites to multiply under axenic culture (Black and Vanderweed, 1989). This could partly explain the decrease in serum HDL-cholesterol and LDL-cholesterol Levels in *T. congolense*-infected animals.

Also, blood-stream forms of trypanosomes, which are unable to synthesize cholesterol, are known to require it along with phospholipids and total lipids for synthesis of their membranes and growth (Black and Vanderweed, 1989; Hue et al., 1990; Katunguka-Rwakishaya et al., 1991; Green et al., 2003; Nok et al., 2003). The continuous removal and utilization, from the blood-stream, of these molecules could partly be responsible for the lowered serum levels of lipids and total cholesterol observed in the present and previous studies. Impaired synthesis and subsequent release of cholesterol from the liver could also be a contributory factor to the decrease in serum levels of total cholesterol observed in the trypanosome-infected animals in the present study. This is because pathologic changes occurring as a consequence of trypanosome infection have been reported in the liver (Logan-Henfrey et al., 1992). Impaired synthesis of cholesterol in the liver could also be the result of insufficient hepatocellular respiration due to hypoxia

caused by anaemia in the *T. congolense*-infected sheep in the present study. Also, lowered LDL-cholesterol serum level such as observed in the present study could retard cholesterol transport from the liver and contribute to its lowered serum level.

Furthermore, blood-stream forms of some trypanosomes scavenge blood glucose as a source of energy (Chaudhuri et al., 2006). This may partly contribute to the development of hypoglycemia observed in some trypanosome-infected animals. Although blood glucose was not determined in the present study, hypoglycemia induced by the trypanosome infection could undoubtedly result in increased catabolism of lipids in order to meet some strategic energy needs in the body of the host animal. Gluconeogenesis from lipids for some essential physiological processes in the body could also cause lowered lipids and cholesterol serum levels. Depressed feed intake of animals, typically associated with trypanosomiasis (Reynolds and Ekwuruke, 1988) and such as the one observed in the trypanosome-infected animals in the present experiment could ultimately reflect on the nutritional status of the affected animals and, hence, the lowered serum concentrations of lipids and cholesterol. Increased serum non-esterified fatty acids in trypanosome-infected animals has led to the suggestion that lipolysis is the major mechanism for supplying the high energy demanded by the fever following trypanosome infection (Akinbamijo et al., 1992). Indeed, Faye et al. (2005) reported that the high energy demands of trypanosome infection may lead to severe energy shortage and this might be reflected in the changes to energy and protein metabolism.

The role of decrease in the serum concentrations of lipids and cholesterol in the pathophysiology of some of the disorders reported in trypanosome-infected animals can better be appreciated when the functions of such lipids and cholesterol in the mammalian physiology are taken into cognizance. Cholesterol is produced in the liver as well as being supplied to the body in human and animal diets. Cholesterol is the building block for cell membranes and it is essential in the formation of bile (which aids in the digestion of fats), vitamin D, other steroids and hormones such as progesterone, testosterone and oestrogen. Cholesterol helps secure proteins involved in cell signaling, allowing for example, neurons to find each other when forming synapses, the formation of which is a basic part of learning and the formation of memories. LDL-cholesterol is the major cholesterol carrier in the blood and is responsible for transporting cholesterol from the liver to organs and tissues of the body. HDL-cholesterol on the other hand is responsible for carrying cholesterol from various organs and tissues to the liver for recycling or degradation. Consequently, any significant alteration in the serum levels of these molecules could result in disorders in affected animals. Many of such disorders have been reported occurring sequel to trypanosome infection in animals. For example,

reproductive endocrine disorders that could impair the reproductive performance of the trypanosome-infected animals have been reported. Reduction in serum concentration of cholesterol may partly be responsible for the reported decline in serum levels of testosterone following trypanosome infection in male animals (Llewelyn et al., 1987; Mutayoba et al., 1994; Sekoni, 1994; Adamu et al., 2004, 2006, 2007). Testosterone plays essential role in the regulating some reproductive functions in male animals. It has been clearly shown that during trypanosome infection, the host's physiology can be dramatically altered with changes in blood pH, hormonal and nutrient concentration plus fever (Seed, 2001).

Although free fatty acids have not been determined in the present experiment, it has been shown that autolysing trypanosomes release such compounds (Assoku et al., 1977). Mostly, stearic, linoleic, palmitic and oleic acids were reported to be generated. These free fatty acids are potentially cytotoxic and haemolytic *in vitro*. Their increase in trypanosome-infected animals may confirm their cytotoxic properties on erythrocytes of the host animals and hence their contribution to anemia and other tissue pathological changes (Biryomumaisho et al., 2003).

The pathogenesis of neurological involvement in human African trypanosomiasis is not currently understood, but it is thought to involve autoimmune mechanisms as in Chagas' disease (Jauberteau et al., 1994; Rhind et al., 1997). Significant decrease in serum lipids and cholesterol levels, such as observed in the present study, may contribute to the development of the reported neurological disorders since cholesterol is vital in cell signaling, a phenomenon that allows neurons to find each other when forming synapses.

In conclusion, *T. congolense* infection resulted in a drop in serum concentrations of lipids and cholesterol in sheep. The significance of the reduction in serum levels of these molecules on the pathogenesis of African trypanosomiasis can be viewed from two perspectives; first that the rapid depletion of the serum lipids and cholesterol re-affirms earlier suggestions that these molecules are, probably, essential in some of the parasite's metabolic processes for it to thrive and cause disease in the animal host. Secondly, the decrease in the serum levels of lipids and cholesterol could have deleterious effects on some body systems, which could result in derangement of their functions. Thus, fall in serum levels of lipids and cholesterol may be one of the pathophysiological mechanisms in the development of some of the reported disorders observed in trypanosome-infected animals. Further investigations are undoubtedly needed to elucidate the biochemical differences that exist in the lipid and cholesterol metabolism between the animal host and trypanosome parasite so that metabolic targets could be identified in the parasite with the view to incorporating the knowledge in the design and development of chemotherapeutic agents.

ACKNOWLEDGEMENTS

The authors wish to express their profound gratitude to the staff of Veterinary Clinical Pathology and Chemical Pathology Laboratory units of the Department of Veterinary Pathology and Microbiology, and University Teaching Hospital, respectively, in Ahmadu Bello University, Zaria, Nigeria, for the technical assistance they provided when carrying out this work.

REFERENCES

- Adamu S, Fatihu MY, Useh NM, Mamman M, Sekoni VO, Esievo, KAN (2004). Effect of experimental *Trypanosoma vivax* infection on serum testosterone levels in Zebu bulls: a preliminary report. *Sok. J. Vet. Sci.* 6: 14-17.
- Adamu S, Fatihu MY, Useh NM, Mamman M, Sekoni VO, Esievo KAN (2006). Testicular pathologic changes in relation to serum concentrations of testosterone in *Trypanosoma vivax*-infected White Fulani bulls. *J. Anim. Vet. Adv.* 5: 1165-1171.
- Adamu S, Fatihu MY, Useh NM, Mamman M, Sekoni VO, Esievo KAN (2007). Sequential testicular and epididymal damage in Zebu bulls experimentally infected with *Trypanosoma vivax*. *Vet. Parasitol.* 143: 29-34.
- Airauchi L (2001). Human sleeping sickness in Nigeria: Knowledge, attitude and beliefs in a focus in the Abraka belt, Delta State of Nigeria. *Afr. J. Clin. Exp. Microbiol.* 2: 6-9.
- Akinbamijo OO, Hamminga BJ, Wensing TH, Brouwer BO, Tolkamp BJ, Zwart D (1992) The effect of *Trypanosoma vivax* infection in West African Dwarf goats on energy and nitrogen metabolism. *Vet. Q.* 14: 95-100.
- Anonymous (2006). Cholesterol (CHOL) enzymatic method manual, RANDOX Laboratories Ltd., Ardmore, Diamond Road, Crumlin, Co. Antrim, United Kingdom.
- Assoku RKG, Tizard IR, Nielsen KH (1977). Free fatty acids, complement activation and polyclonal B-cell stimulation as factors in the immunopathogenesis of African trypanosomiasis. *Lancet.* 2: 956-959.
- Biryomumaisho S, Katunguka-Rwakishaya E, Rubaire-Akiiki CM (2003). Serum biochemical changes in experimental *Trypanosoma congolense* and *Trypanosoma brucei* infection in East Africa sheep. *Vet. Arch.* 73(3): 167-180.
- Black S, Vanderweed V (1989). Serum lipoproteins are required for multiplication of *Trypanosoma brucei brucei* under axenic culture conditions. *Mol. Biochem. Pathol.* 37: 65-72.
- Chaudhuri M, Ott RD, Hill GC (2006). Trypanosome alternative oxidase: from molecule to function. *Trends Parasitol.* 22: 484-491.
- Daniel AD, Dadah AJ, Kalejaiye JO, Dalhatu AD (1993). Prevalence of bovine trypanosomiasis in Gongola State of Northern Nigeria. *Rev. Med. Vet. Trop.* 46 (4): 571-574.
- Darsaud A, Bourdon L, Chevrier C, Keita M, Bouteille B, Queyroy A, Canini F, Cespluglio R, Dumas M, Buguet A (2003). Clinical follow-up in rat experimental model of African-trypanosomiasis. *Exp. Biol. Med.* 228: 1355-1362.
- Diehl EJ, Risby L (1974) Serum changes in rabbits experimentally infected with *Trypanosoma gambiense*. *Am. J. Trop. Med. Hyg.* 23: 1019-1021.
- Dumas M, Bouteille B, Buguet A (1999). Progress in Human African trypanosomiasis, Sleeping Sickness. 1st ed. Paris: Springer Verlag. p. 344.
- Esievo KAN, Saror DI, Ilemobade AA, Hallaway MH (1982). Variation in erythrocyte surface and free serum sialic acid concentrations during experimental *Trypanosoma vivax* infection in cattle. *Res. Vet. Sci.* 32: 1-5.
- Esievo KAN, Saror DI (1991). Immunochemistry and Immunopathology of animal trypanosomiasis. *Vet. Bull.* 61: 765-777.
- FAO (2002). Food, agriculture and food securities; the global dimension, WFSO2/Tech/Advanced unedited version, FAO, Rome. pp. 19-28.
- Faye D, Fall A, Leak S, Losson B, Geerts S (2005). Influence of an experimental *Trypanosoma congolense* infection and plane of nutrition on milk production and some biochemical parameters in West African Dwarf goats. *Acta Trop.* 93: 247-257.
- Friedewald W, Levy R, Fredrickson D (1972). Estimation of concentration of low density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin. Chem.* 18: 499-502.
- Gibbons A (1992). Researchers fret over neglect of 600 million patients. *Science* 256: 1135
- Green HP, Portela MPM, St Jean EN, Lugli EB, Raper J (2003). Evidence for a *Trypanosoma brucei* lipoprotein scavenger receptor. *J. Biol. Chem.* 278: 422-427.
- Greenwood BM, Whittle HC (1980). The pathogenesis of sleeping sickness. *Trans. Roy. Soc. Trop. Med. Hyg.* 74: 716-723.
- Halid L (2001) Tsetse and trypanosomiasis in Nigeria 1999-2001 ISCTRC (OAU/STRC) Ougadougou, Burkina Faso.
- Hue G, Lemsre JL, Grard G, Boutignon F, Dieu MC, Janinin J, Degand P (1990). Serum lipid and lipoprotein abnormalities in human African trypanosomiasis. *Trans. Roy. Soc. Trop. Med. Hyg.* 84: 792-794.
- Ikede BO, Losos GJ (1972). Pathology of disease in sheep produced experimentally by *T. brucei*. *Vet. Pathol.* 9: 278-289.
- Irunpu P, Nyamwaro SO, Masiga DK (2002). Financial implications of rearing sheep and goat under natural trypanosomiasis challenge at Galana ranch, Kenya. *Trop. Anim. Hlth. Prod.* 34(22): 503-513.
- Katunguka-Rwakishaya E, Murray M, Holmes PH (1991). Haematological erythrokinetic and blood lipid changes in sheep infected with *Trypanosoma congolense*. International Scientific Council for Trypanosomiasis Research and Control (OAU/ISCTRC) 21st Meeting. Publication No. 116. Yamoussoukro, Cote d'Ivoire.
- Katunguka-Rwakishaya E, Murray M, Holmes PH (1992). The pathophysiology of ovine trypanosomiasis: haematological and blood biochemical changes. *Vet. Parasitol.* 45: 17.
- Katunguka-Rwakishaya E, Parkins JJ, Fishwick G, Murray M, Holmes PH (1995). The influence of energy intake on the pathophysiology of *Trypanosoma congolense* infection in Scottish blackface sheep. *Vet. Parasitol.* 59: 207-218.
- Kristjanson PM, Swallow BM, Roulands GJ, Kruska RL, de Leeuw PN (1999). Measuring the cost of African animal trypanosomiasis, the potential benefits of control and returns to research. *Elsevier Agric. Syst.* 59: 79-98.
- Llewelyn CA, Luckins AG, Munro CD, Perrie J (1987). The effect of *Trypanosoma congolense* infection on the oestrous cycle of the goat. *Br. Vet. J.* 143: 423-431.
- Logan-Henfrey LL, Gardiner PR, Mahmoud MM (1992). In: Kreier JP, Baker JR (Eds) Parasitic Protozoa, 2. Sandiego Academic Press, pp 157-275.
- Molyneux DH, Pentreath V, Doua F (1996). African trypanosomiasis in man. In: Cook GC (Ed) Mason's Trop. Dis. 63: 1171-1196.
- Mutayoba BM, Eckersall PD, Jeffcoate IA, Cestnik V, Holmes PH, (1994). Effects of *Trypanosoma congolense* infection in rams on the pulsatile secretion of testosterone and response to injection of GnRH. *J. Rep. Fer.* 102: 425-431.
- Nakamura Y (1998). Alterations of serum lipid, lipoprotein and inflammatory cytokine profiles of rabbits infected with *Trypanosoma brucei*. *Vet. Parasitol.* 80:117-125.
- Nantulya VM (1990). Trypanosomiasis in domestic animals: The problem of diagnosis. *Rev. Sci. Tech. Off. Int. Epizoo.* 9: 357-367.
- Neils JS, Esievo KAN, Adamu S, Sackey AKB, Abdullahi US (2007). Effect of *Trypanosoma congolense* infection on serum concentration of Yankassa sheep. *J. Anim. Vet. Adv.* 6: 46-48.
- Nok AJ, Balogun EO (2003). A bloodstream *Trypanosoma congolense* sialidase could be involved in anemia during experimental trypanosomiasis. *J. Biochem.* 133: 725-730.
- Nok AJ, Nock AH, Bonire JJ (2003). The cholesterol pathway of *Trypanosoma congolense* could be a target for triphenylsilyl-salicylate inhibition. *Appl. Organomet. Chem.* 17: 17-22.
- Odoya EM, Omotainse SO, Thompson GA (2003) Prevalence of trypanosomiasis in goats in Abraka, Delta State of Nigeria. *Niger. Vet. J.* 24: 42-43.
- Ogunsanmi A, Taiwo V, Onawumi B, Mbagwu H, Okoronkwo C (2000). Correlation of physiological plasma lipid levels with resistance of cattle to trypanosomiasis. *Vet. Arch.*, 70: 251-257.

- Paris J, Murray M, McOdimba F (1982). A comparative evaluation of parasitological techniques currently available for the diagnosis of African trypanosomiasis in cattle. *Acta Trop.* 39: 307-316.
- Rouzer CA, Cerami A (1980). Hypertriglyceridaemia associated with *Trypanosoma brucei brucei* infection in rabbits: role of defective triglyceride removal. *Mol. Bioch. Parasitol.* 2: 31-38.
- Reynolds L, Ekwuruke JO (1988). Effect of *Trypanosoma vivax* infection on West African Dwarf sheep at two planes of nutrition. *Small Rum. Res.* 1: 175-188.
- Rhind SG, Sabiston BH, Shek PN, Buguet A, Muanga G, Stanghellini A, Dumas M, Radomski MW (1997). The effect of melarsoprol treatment on circulating IL-10 and TNF- α level in human African trypanosomiasis. *Clin. Immunol. Immunopathol.* 83: 185-189.
- Seed JR (2001). African trypanosomiasis research: 100 years of progress, but questions and problems still remain. *Int. J. Parasitol.* 31: 434-442.
- Sekoni VO (1994). Reproductive disorders caused by animal trypanosomiasis: a review. *Theriogenology*, 42: 557-570.
- Shamaki BU, Yanan EG, Omotainse SO, Kalejaiye JO, Balak GG Halid I (2002). Prevalence of ruminant trypanosomiasis and other blood parasites in some parts of Plateau State of Nigeria. Proceedings of the 39th Annual Congress of Nigerian Veterinary Medical Association, Sokoto, October 27th-31st, 2002.
- Swallow BM (2002). Impact of trypanosomiasis on Agriculture. PAAT Technical and Scientific Series, 2: 35-38.
- Smith DH, Pepin J, Stich AHR (1998). Human African trypanosomiasis: an emerging public health crisis. *British Medical Bulletin* 54: 341-355.
- Steel RGD, Torie M (1980). Principles and procedures in statistics, 2nd Ed. McGraw-Hill, New York pp. 782-789.
- Tewe OO (1999) Post harvest technologies fro research Institutes and Universities of Nigeria. Compiled by Technological Vision Organization (TECHNIVISOR) in the United Nations Development programme.
- Welde BT, Reardon MJ, Kovatch RM, Chumo WT, Wykoff DE (1989). Experimental infection of cattle with *Trypanosoma brucei rhodesiense*. *Ann. Trop. Med. Parasitol.*, 83: 133-134.
- Woo PTK (1969). The haematocrit centrifuge techniques for the detection of trypanosomes in blood. *Can. J. Zool.* 43: 921-923.