# HAEMATCLOGY, SERUM IRON AND IRON-BINDING CAPACITY OF APPARENTLY NORMAL AND TRYPANOSOME INFECTED ZEBU CATTLE

by

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ABSTRACT

# INTRODUCTION

Inadequate nutrition and diseases of cattle are major constraints limiting the availability of animal protein for the increasing population of Nigeria.

Trypanosomiasis has long been recognized as a major disease and vast areas of the country have been rendered unsuitable for economic livestock production because of its prevalence.

Trypanosomiasis in Nigerian cattle is caused by two principal trypanosomes: Trypanosoma congolense and Trypanosoma vivax. These trypanosomes alone or in combination with other protozoal parasites produce a chronic debilitating and often fatal disease that is characterised by anaemia.

The mechanism responsible for the anaemia in trypanosomiasis has been the subject of numerous investigations. Several factors including bone marrow hypoplasia, hydraemia, haemolysis and dyshaematopoiesis have been suggested as mechanisms responsible for the anaemia. There has been no concensus of opinion on the pathogenesis of the anaemia but there is general agreement that there is erythrocyte destruction. Factors mediating the process and the nature of the erythrocyte destruction remain obscure.

Control and treatment of trypanosomiasis is dependent upon a more complete understanding of the pathogenesis of the disease. The primary objective of this study was to evaluate the clinico-pathologic aspects of trypanosomiasis with emphasis on mechanisms involved in the development of anaemia.

In order to study the clinico-pathologic alterations in trypanosomiasis it was essential to first establish normal values in local and exotic breeds of cattle under several management and environmental conditions. Base-line haematologic parameters of apparently healthy Fulani, Friesian, and Fulani/Friesian (crossbred) cattle maintained under improved management and with local husbandry practices, were established. The extent and nature of serum iron and iron-binding capacity in native cattle was also determined as were daily variations and the influence of age on these parameters.

Using normal values as a baseline the alterations in haematology and iron metabolism were studied in native cattle experimentally infected with Trypanosoma vivax and Trypanosoma congolense.

In addition, the reticulo-endothelial organs were examined histologically to evaluate haematopoietic response and the role of these organs in the development of anaemia.

# I: REVIEW OF LITERATURE

## Basic Concepts of Iron Metabolism

Iron performs its most essential and most critical functions in the animal body by combining with protoporphyrin to form heme. Heme combines with various protein moieties to form heme enzymes such as cytochromes, catalase and peroxidase which make oxygen available for intracellular oxidation. The subject of iron metabolism in man and domestic animals has been the topic of several reviews (Kolb, 1963; Brown, 1966; Pollycove, 1966; Kaneko, 1970). Body iron stores may be divided into two main categories: (a) an essential functional component of haemoglobin, myoglobin, enzyme and co-factor iron and plasma transport iron and (b) a non essential storage component made up of ferritin, haemosiderin and other storage components, which provide a reserve of iron readily mobilizable into an essential functional component (Brown, 1966).

Intestinal absorption of iron is of importance in iron metabolism as iron balance is regulated by controlled absorption rather than excretion. The subject of iron absorption in man and domestic animals has been reviewed by Kolb (1963) and Conrad (1970). The simplest model of iron absorption has been viewed as consisting of two stages:

(1) the mucosal uptake of dietary iron, and (2) the transfer of iron from intestinal cells into the body. This model provides three anatomic locations for studying regulatory factors. (a) intraluminal, (b) mucosal absorptive cells, and (c) corporeal (Conrad and Crosby, 1963; Conrad et al., 1964; Wheby et al., 1964).

Intraluminal factors affecting iron absorption include: quantity of ingested iron, physical and chemical form of iron, presence of chelating and precipitating substances, and gastro-intestinal secretions such as hydrochloric acid, ascorbic acid, glutathione, bicarbonates and other pancreatic secretions (Conrad and Schade, 1968; Schade et al., 1968).

Mucosal factors known to influence iron absorption in man and animals have been listed by Conrad (1970). Experimental evidence indicates that: (a) enhanced absorption occurs with iron deficiency, and decreased absorption with iron overloading (Bothwell et al., 1958); (b) factors which stimulate erythropoiesis enhance iron absorption whereas diminished absorption occurs with decreased erythrocyte production (Bothwell et al., 1958); (c) the amount of iron absorbed is usually a small percentage of ingested iron (Smith and Pannacciulli, 1958); (d) the duodenum is the most efficient site of

absorption and it remains attuned to body iron requirements (Wheby et al., 1964); (e) small intestinal mucosal cells act to regulate the entry of iron into the cell (Conrad and Crosby, 1963; Conrad et al., 1964; Conrad et al., 1965); (f) duodenal absorption of iron involves an active transport mechanism consisting of mucosal uptake of iron from the intestinal lumen and the mucosal transfer of iron into the body. Both steps are affected inversely by the state of body iron stores (Conrad, 1970); (g) iron deficiency increases intestinal absorption of non-ferrous metals such as cobalt and manganese (Pollack et al., 1965; Schade, et al., 1970).

It has been postulated (Conrad et al., 1964) that iron is absorbed from the lumen of the gut into duodenal mucosal cells and transferred from these cells into the body. The quantity of iron in mucosal cells remains in equilibrium with labile body iron stores: the quantity absorbed depends upon the current body requirements. The regulation of iron absorption is believed to be mediated through the iron-ferritin complex. As iron enters the intestinal mucosal cells, it unites with the protein apoferritin to form ferritin. It is in this form that iron is subsequently transferred to the body.

Two corporeal factors are usually cited as important

stimuli to iron absorption. These are the rate of erythropoiesis and the tissue iron stores (Beutler et al., 1963). Accelerated erythropoiesis is related to enhanced iron absorption whether the stimulus is blood loss, haemolysis or hypoxia. Conversely, diminished erythropoiesis decreases iron absorption (Bothwell et al., 1958; Weintraub et al., 1965; Chirasiri and Izak, 1966; Conrad et al., 1967). Corporeal factors are believed to be the most important regulators of iron absorption. However, the mechanism by which they inform the duodenum to transfer appropriate amounts of iron into the plasma is unknown (Conrad, 1970).

*Humoral factors which enhance or inhibit iron* absorption have been sought but have not been consistently demonstrated (Krantz et al., 1959; Beutler and Buttenweiser, 1960; Conrad, 1969; Conrad, 1970).

Kassirsky and Alexeev (1972) summarized the process of ionization, absorption and storage of alimentary iron schematically as follows:

Food → Stomach → Small Intestine the duodenum (mucosal cells) → Blood (Plasma) → Depot organs (Liver, spleen, bone marrow)

$Fe^{+++}$ → $Fe^{++}$ → $Fe^{++}$ + apofer- → Ferritin → Ferritin
ritin ferritin +β-globulin iron-trans-ferrin compound haemosiderin

Once iron is absorbed into the bloodstream, it immediately combines with a specific protein "transferrin" (also called plasma iron-binding protein and siderophilin). Transferrin is a globular protein with a molecular weight of about 88,000. It functions in the transport of iron from the intestinal sites of ~~haemoglobin breakdown~~ absorption to the bone marrow, to other tissues requiring iron and to various storage sites. Each molecule of transferrin binds two atoms of ferrous iron. In normal plasma, there are more transferrin iron-binding sites than atoms of iron (Laurell, 1951; Pollycove, 1966; Brown, 1966; Fletcher and Huehns, 1968). Transportation of iron from the intestine to the liver and from the liver to other storage organs such as the spleen and bone marrow is limited by the availability of plasma transferrin.

Plasma iron is one of the iron-transport systems of the body (Beutler; 1957) but is not an iron storage pool as plasma iron is continuously being renewed. Kaneko (1963) estimated that in the cow, plasma iron is "turned" over" approximately every three hours. The concentration of iron in the plasma at any moment is a function of the iron entering the plasma (from erythrocyte destruction, iron absorbed from the gastro-intestinal tract, and iron

released from stores) and in the iron leaving the plasma to the storage sites or for haemoglobin synthesis (Beutler, 1957).

Numerous procedures are available for the measurement of serum iron (SI) concentration. Colourimetric techniques are most commonly used. These depend on the formation of coloured complexes of serum iron and compounds such as orthophenanthroline (Barkan and Walker, 1940) and 2, 4, 6 - tripyridyl - s-triazine (Collins et al., 1959).

Measurements of transferrin in clinical practice are indirect and depend upon measuring its iron-binding capacity. The capacity of plasma to bind added iron is referred to as the unsaturated iron-binding capacity (UIBC) (Cartwright and Wintrobe, 1949).

Iron-deficiency anaemias are associated with low SI (Beutler, 1957; Blaxter et al., 1967; Furugouri, 1972). The iron-binding capacity of plasma generally increases in acute or chronic infections and haemolytic anaemia. The behaviour of iron in various disease states has been recently summarized by Kaneko (1970) and is presented in Table 1.

## Serum Iron Metabolism in Calves

There is considerable variation in SI in normal calves. Mean normals from 60 ug/dl to 240 ug/dl have been reported (Matrone et al., 1957; Lanz, 1956; Baker and Douglas, 1957; Hansard et al., 1959; Kolb, 1963; Hibbs et al., 1963).

Matrone et al., (1957) reported that SI did not vary significantly with age in cattle from 4 months to 7 years of age. Lanz (1956) found that new-born calves had high SI that decreased after a few days. However, SI rose quickly as calves began to ingest vegetable feeds. Kolb (1959) investigated the SI and total iron-binding capacity (TIBC) in calves and cows brought to slaughter. His results showed that serum iron and iron-binding capacity of calf serum was higher than in mature cattle.

Gurtler and Schutzler (1971) studied the iron and copper status of new-born calves. The calves were sampled shortly after birth and at 2, 24, 48, 96 and 240 hours after the first intake of colostrum. They found that SI was high after birth (mean 159 ug/dl) but fell to 69 ug/dl 96 hours later. The TIBC fell on the first day but rose from 37 ug/dl at 24 hours to 605 ug/dl on the 19th day. Iron saturation of transferrin was lowest on the 4th day.

Knoop et al., (1935) found that calves developed a nutritional anaemia when fed exclusively on milk. Blaxter et al., (1957) also reported iron deficiency anaemia in calves on a milk diet. Iron-deficiency anaemia was also observed in calves raised under farm conditions. The anaemia was microcytic and normochromic and associated with poikilocytosis; there were many metarubricytes in the bone marrow.

There are few ferrokinetic studies in calves and results are inconclusive. Hansard and Foote (1959) carried out ferrokinetic studies of plasma iron (PI) in calves and reported that it was "turned over" every 3 hours on the average. Baker and Douglas (1957) reported that calf serum iron was "turned over" about 9.1 times in 24 hours or every 2.64 hours.

Bremner and Ronalds (1965) studied the effect of acute haemorrhage on SI and TIBC in calves. When 900, 1780 and 2780 ml of blood was removed from calves during a 24 hour interval, the SI rose after a week and reached a maximum between 11 and 15 days after haemorrhage. The mean TIBC values declined ~~and~~ but by day 54 had returned to pre-bleeding levels.

Results of this experiment showed that the TIBC of calf plasma increased following haemorrhage. Similar

findings have been reported in man, rat and rabbit (Laurell, 1947). The increased SI concentration observed in calves after experimental haemorrhage was attributed to increased mobilization of labile iron reserves.

When 260, 520, 730 ml of blood were removed daily for 14 days from 3 sets of calves respectively, the SI in calves that lost 260 and 520 ml daily rose gradually, reaching a peak 10 days later. The elevated SI was maintained until phlebotomy was discontinued. The SI decreased to normal on the twenty-fourth day of the experiment. However, in the group that lost 730 ml of blood daily for 14 days, SI decreased markedly, reaching a minimum mean value of 32 ug/dl after 14 days of phlebotomy. This probably occurred as iron stores were depleted. When phlebotomy was discontinued, the SI rose sharply reaching a high peak of 310 ug/dl on the seventh day. The SI subsequently decreased reaching normal values 3 weeks later. The sharp increases in SI following 14 days of haemorrhage were believed to be due to increased absorption of iron from the gastro-intestinal tract.

Bremner (1966) investigated the variation of SI and TIBC in dairy calves from birth to 15 months of age. In most calves, SI increased considerably between one and

3 weeks after birth, then declined within the next few days to levels similar to those found in adult cattle. The TIBC of serum increased sharply after birth and reached maximum values between one and 5 weeks later. Thereafter, TIBC declined up to 3 months of age. In calves 3 to 15 months of age, the SI of female calves decreased with age and by 15 months was significantly lower than in male calves of the same age. The TIBC of all calves increased with age from 3 to 15 months but no sex differences were observed.

Although no conclusions were made concerning mechanisms controlling iron metabolism in very young calves, the data suggested that marked changes in iron transport and turnover may have occurred in early life.

An investigation into the effect of age on SI and TIBC in Zebu cattle was recently completed (Tartour, 1973). Serum iron levels did not vary significantly among calves, heifers and young adult cows 4 to 7 years of age. The highest SI was recorded in heifers and the lowest in calves. Cows 8 years and older had progressively lower SI with advancing age. Only slight differences in TIBC were found between calves and heifers. The highest TIBC values were recorded in cows

4 and 7 years of age. Successively lower values were recorded in older cows. The saturation concentration (SC) did not vary with age. Values for heifers, however, were relatively higher than for calves or adult cows.

The author concluded that in Zebu cattle, both SI and TIBC progressively fell with advancing age while the SC remained fairly constant throughout life.

## Serum Iron Metabolism in Adult Cattle

A number of workers have reported on SI, UIBC, TIBC and SC in adult cattle. The values are presented in table 2. Serum iron in adult cattle was generally lower than in calves (Kolb, 1963; Tartour, 1973). An increase in SI was recorded in pregnant cows close towards the end of gestation. The biological or statistical significance of the increase was not determined. Kolb (1963) observed that adult cattle had lower SI and TIBC than calves. Similar findings have been reported by Tartour (1973) in Zebu cattle. Bartko (1960) observed that among sexually mature cattle, females had somewhat lower average SI than males. Planas (1963) investigated SI in normal and castrated bulls and found no significant difference. However, TIBC was lower in castrated than in intact males. Planas and De Castro (1960) investigated SI and TIBC in various mammals. Serum iron did not show

any significant intersexual or interspecies differences. There were marked differences between species in TIBC, particularly in cows and man. Matrone et al., (1947) investigated SI in dairy cattle but found no evidence that SI changed with age. No significant differences in SI were found among the Holstein, Ayrshire, Guernsey and Jersey breeds of cattle. However, SI varied from period to period.

## Disturbances in Iron Metabolism in Cattle with Parasitic Diseases

Many parasitic diseases are accompanied by disorders of iron metabolism associated with anaemia (Jennings et al., 1956, Hansard et al., 1959; Campbell and Campbell-Gardiner, 1960; Tartour and Idris, 1973). These disorders occurred as a consequence of blood loss, an increased rate of destruction of erythrocytes, or because of suppression of haematopoiesis as a consequence of the direct or indirect action of parasitic infections.

Alterations of iron metabolism in cattle with parasitic infections have not been extensively investigated. Baker and Douglas (1957) carried out ferrokinetic studies in calves suffering from trichostrongylosis. Calves, 3 months of age, required 0.81 mg per kg of iron

per day, of which 68% was utilized for haemoglobin synthesis. The SI was 170 ug/dl and the TIBC was 90 ug/dl with 65 per cent transferrin saturation. Thus the UIBC and TIBC were below normal while the SI level was normal. Mean erythrocyte survival time was 11 days. The $T\frac{1}{2}$ for plasma iron clearance was 1.04 hours, representing a complete turn-over of SI every one and one-half hours. It was concluded that anaemia in chronic trichostrongylosis was due primarily to five-fold shortening of erythrocyte survival time and to some inhibition in ability of the marrow to increase haemoglobin production. It was postulated that the anaemia may have been due to a specific nutrient deficiency or to a multiple deficiency that resulted from parasitic activity. No experimental evidence to support this conclusion was given.

Hansard and Foote (1959) investigated the disturbances in iron metabolism during anaplasmosis in calves using ferrokinetic and erythrokinetic procedures. Three to 7 days prior to peak appearance of Anaplasma bodies in erythrocytes, there was a marked reduction in the utilization of iron for haematopoiesis as evidenced by a markedly decreased SI clearance and an increased SI. During the recovery phase, SI clearance

was accelerated and SI decreased which suggested an accelerated increase in erythropoiesis during the recovery phase. Erythrokinetic data revealed a markedly decreased erythrocyte life span during the course of the disease. While the exact mechanism of the anaemia was not determined, it was felt to have arisen as a result of:

(a) an increased rate of erythrocyte destruction or
(b) the intensified efforts to compensate for the prevailing anaemia resulting in the release of immature and/or malformed red blood cells into the circulation, or
(c) a combination of these factors.

The apparent absence of haemoglobinuria and haemoglobinaemia during anaplasmosis suggested that the anaemia was not due to massive intravascular destruction of erythrocytes.

Tartour and Idris (1973) investigated the behaviour of SI and serum UIBC in Zebu cattle with experimentally induced Trypanosoma congolense infection. During the first week of infection, both SI and UIBC decreased. By the third week of infection there was a slight increase in SI, accompanied by a reduction of UIBC. As the disease advanced into its chronic phase, there was an

irregular pattern of increased and decreased SI and UIBC. The periodic increases in SI were attributed to an accelerated rate of erythrocyte destruction during haemolytic episodes. The sharp fall in UIBC exhibited by most calves was believed to be due to excessive saturation of transferrin by iron liberated from destroyed erythrocytes. Full saturation of transferrin appeared to be a constant feature of collapse before death both in acute and chronic T. congolense infections.

## Clinico-Pathologic Aspects of Bovine Trypanosomiasis

Trypanosomiasis is the most important blood parasitic disease of livestock in Nigeria. Practically all mammals are susceptible to one or more trypanosome species. Trypanosomes are widely distributed throughout tropical Africa, being transmitted by tsetse flies of the genus Glossina. Consequently, vast areas of tropical Africa have been rendered unsuitable for economic livestock production.

The characteristics of pathogenicity, transmission, distribution and epidemiology of trypanosomiasis in man and animals has been a most challenging study in medical and veterinary science since the turn of the century (Duggan, 1970). The pathology of trypanosomiasis has been the subject of several recent reviews (Hoare, 1970a, 1970b; Losos and Ikede, 1972). The role of trypanosomes and trypanosomiasis in African ecology was the subject of a recent review (Ford, 1971).

Trypanosomiasis is caused by a flagellated protozoan belonging to the genus Trypanosoma. Trypanosomes are uniform in type but vary in morphological details which are of taxonomic significance (Hoare, 1970b). Many

species of mammalian trypanosomes are recognized but not all are pathogenic. Pathogenic species vary widely in their degree of pathogenicity in a given host and strains within a species may vary in virulence.

Trypanosoma vivax (T. vivax) and Trypanosoma congolense (T. congolense) are the chief causes of bovine trypanosomiasis in Africa (Leeflang, 1974). There is considerable variation in virulence and pathogenicity of the different strains of T. vivax and T. congolense. West African T. vivax is more pathogenic to Zebu cattle than East African strains (Fairbairn, 1953). Differences in the course of infection by T. congolense have also been described and it is generally believed that in Nigeria, compared with East Africa, the organism is characterized by lower infectivity, pathogenicity and parasitaemia. The dimorphon type of T. congolense, however, is very virulent in Nigerian livestock (Godfrey, 1961). The relative prevalence of T. vivax and T. congolense infections in Nigerian cattle appeared variable, not only during successive years but also for different parts of the country.

In table 3, the relative prevalence in the former Zaria Province is summarized. The higher prevalence of

T. congolense in more recent years has been explained by various reasons:

1. the fact that Fulani cattle owners were forced to enter and exist in previously avoided tsetse-infested areas due to overgrazing and water shortage in tsetse free areas (Wilson, 1958).
2. the possibility that T. congolense might be inherently less drug-sensitive than T. vivax (Williamson and Stephen, 1960) and
3. the widespread use of Homidium to which T. congolense became easily resistant whereas T. vivax remained generally susceptible to this drug (Jones-Davies and Folkers, 1966; Folkers et al., 1968).

The preponderance of either T. vivax or T. congolense in different parts of the country was illustrated by Ilemobade (1971) who, in the former Katsina Province, identified 20% of the trypanosome infections as T. congolense and 80% as T. vivax while in the former Zaria Province these figures were 58.5% and 37.8% respectively (mixed infections not included).

Folkers and Davies-Jones (1966) demonstrated that, following removal of Zebu cattle infected with trypanosomes from areas where cyclical transmission was occurring, T. vivax progressively became the predominant infection. The ratio beween T. vivax and T. congolense infections was not affected when cattle remained in a tsetse infested area. Also when susceptible cattle were freshly exposed to the risk of contracting trypanosomiasis, T. vivax was the predominant species (Maclennan, 1970; Leeflang, 1974). Ecological factors that may account for the predominance of T. vivax or T. congolense infections in certain parts of Nigeria have been described (Folkers and Jones-Davies, 1966; Ford, 1971; Leeflang, 1975).

The three main breeds of cattle in Nigeria viz Zebu, Muturu and N'Dama, and their cross-breds have varying degrees of susceptibility to trypanosomiasis. The Muturu and N'Dama breeds are fairly resistant (Chandler, 1952; Desowitz, 1959; MacLennan, 1970; Weitz, 1970 and Roverts and Gray, 1973). Zebu cattle are highly susceptible to trypanosomes while crosses between N'Dama or Muturu and Zebu occupy an intermediate position. These variations in susceptibility among other factors have profound influence on cattle husbandry and breed distribution patterns in Nigeria and contribute to the

nomadic way of life adopted by the majority of the Zebu cattle owners (Leeflang, 1974).

Clinical Manifestations of Bovine Trypanosomiasis:

The pathogenicity of T. vivax and T. congolense varies within wide limits even in the same host species. The clinical manifestations and course of trypanosomiasis in cattle may be influenced by many factors including resistance, standards of husbandry and nutrition, presence of concurrent infections, stress due to vaccinations, trekking and pregnancy (Stephen, 1970).

In West Africa, infection by T. congolense is generally regarded as relatively mild and chronic. Clinical signs include periodic increases in temperature coinciding with increasing parasitaemia. Appetite generally remains good. As the disease progresses, there is a marked anaemia and loss of weight. There may be loss of libido in chronic cases. Terminally, the infected individual may be unable to rise, have difficulty with respiration and have a pronounced jugular pulse. Death may occur in a few weeks but usually takes several months (Stephen, 1970).

West African T. vivax is highly pathogenic in susceptible cattle, often producing an acute, fatal disease (MacLennan, 1970, Stephen, 1970). Parasitemia is usually

massive and sustained. Affected cattle may die before any loss of condition is evident. Cattle with chronic infections develop anaemia, have a dull hair coat, loss of weight, a jugular pulse and enlarged superficial lymph nodes. In terminal stages, the animal may be unable to rise and die in a state of exhaustion.

Haematology:

Hornby (1929, 1952) and Hornby and Bailey (1931, 1933) showed that T. congolense in cattle was strictly a plasma parasite which was localized in the small blood vessels. These authors regarded the anaemia which accompanied the infection to be primarily responsible for the disease process. This view was challenged by Fiennes (1952) who demonstrated cryptic loci of the parasites in various tissues and organs. Fiennes (1954) investigated the haematological changes found in cattle with T. vivax infections. He recognized four courses of the disease process viz the hyperacute course, the acute course, the chronic course and the recovery course. He attributed the causes of the anaemia to haemolysis, haemodilution, removal and destruction of erythrocytes by the spleen and failure of the bone marrow to replenish red blood cells into the circulation. Fiennes (1954) observed that a severe

anaemia which developed during the acute course was primarily due to removal and destruction of red cells by the spleen and other reticulo-endothelial organs. The anaemia, he claimed, was intensified by haemolysis, produced by haemolysin that emanated from damaged trypanosomes. In acute course, the anaemia was macrocytic. A microcytic anaemia accompanied by low red cell counts and haemoglobin was observed in the chronic course of the disease. The wasting and debilitating condition observed in chronic stages of the disease was attributed to "physiological starvation."

Naylor (1971,a,b,c) maintained that the disease process in T. congolense infection in cattle was essentially chronic and characterized by anaemia, leukopenia, intermittent pyrexia and emaciation. The anaemia was normochromic and macrocytic. The cause of the anaemia was attributed to haemodilution, extravascular haemolysis and dyshaemopoiesis. His data indicated that one week following infection by T. congolense, there was a precipitous drop in circulating erythrocytes, haemoglobin and packed cell volume. These reached a low point in two to three weeks and remained low until the animal died in anaemic crises, a few weeks later. In cattle that survived, there was a gradual

increase in erythrocytes, haemoglobin and PCV. A normochromic, macrocytic anaemia was observed early in infection. Reticulocytosis was not observed. Anisocytosis was the most common morphologic change observed.

Losos et al., (1973) in their studies of the pathology of T. congolense infection in cattle observed that the anaemia was normocytic and normochromic with a conspicuous absence of reticulocytes in the peripheral circulation. The anaemia was accompanied by a persistent leukopenia due to a decrease in neutrophils and lymphocytes with immature neutrophils.being present. The cause of the anaemia was attributed to extravascular haemolysis without accompanying adequate compensatory stimulation of the erythopoietic tissue. Wellde et al., (1974) observed in experimental T. congolense infection in cattle that the PCV began to decrease with the onset of patency. The anaemia was progressive and accompanied by changes in the composition and morphology of the peripheral erythrocytes. Anisocytosis and polychromatophilia were the earliest changes noted. Basophilic stippled cells and normoblasts were found later in some animals. The erythropoietic response was especially prominent during the period between 6th and 9th week. After the 13th week, the erythrocytes were normocytic normochromic.

A leukopenia persisted for the duration of the disease. Especially low leukocyte counts were recorded during high levels of parasitaemia. Segmented neutrophils decreased while a relative increase in mononuclear cells occurred. Holmes and Mamo (1975) demonstrated excessive loss of $^{51}Cr$-labelled erythrocytes from the circulation indicating a reduction in erythrocyte survival time in T. congolense infected calves. These workers observed that as the anaemia developed, there was an absolute fall in circulating erythrocyte mass and an over-compensatory increase in plasma volume. They concluded that haemodilution was of secondary importance in bringing about the anaemia. There was no evidence that dyshaematopoiesis played any part in the aetiology of the anaemia.

Hawkins et al., (1975) have suggested that the early anaemia in T. congolense infected calves was due to a direct toxic action of the trypanosomes upon the blood and that in the initial phase at any rate, it was not due to immune processes or to a depression of erythropoiesis.

Bone marrow cytology:

There have been few systematic studies on bone marrow changes in cattle with trypanosome infection.

Fiennes (1954) observed that the red marrow of the long bones became degenerated and was replaced by yellow marrow and gelatinous material. The marrow of the sternum, ribs and vertebrae appeared to be unaffected. Naylor (1971b,c) observed mild degenerative changes in infected bone marrow. These changes included vacuolation of the cytoplasm and nuclei of young cells in the granulocytic series, and a greater tendency for these cells to disintegrate. Megaloblastoid changes were observed in a small proportion of early cells in the erythrocytic series. Losos et al., (1973) observed hyperplasia of the erythropoietic tissue in the femoral bone marrow. Well defined nests of immature erythrocytes were found throughout the active marrow and megakaryocytes were numerous. Wellde et al., (1974) observed large numbers of metarubricytes in the rib marrow of some animals with T. congolense infection. Leukocytic precursors and megakaryocytes were abundant in all smears. Plasma cells were present in bone marrow smears.

The spleen and lymph nodes:

Microscopic changes in the spleen of cattle with trypanosome infections have been reported. Fiennes (1954) observed that during the pre-critical and critical

states, the spleen was greatly enlarged. The red pulp was most affected, the sinuses being packed with erythrocytes and leukocytes particularly neutrophils and macrophages. Extensive haemosiderin deposits were present either in the macrophages or lying free. He concluded that the spleen was involved in the removal and destruction of erythrocytes from the circulation. This phenomenon, he felt, contributed significantly to the development of anaemia. Erythrophagocytosis and haemosiderin deposits were commonly observed in the lymph nodes. Losos et al., (1973) observed haemosiderosis in the spleen and lymph nodes as well as in the lung, heart, brain and kidney. Splenomegaly was attributed to cellular hyperplasia and erythrocyte pooling in the sinuses. Naylor (1971a) observed a reticular hyperplasia of the spleen and lymph nodes. Haemosiderin deposits were also observed in these organs. Bone marrow of infected cows was hyperplastic with increased haemosiderosis. Kaliner (1974) observed haemosiderosis but no hyperplasia of the spleen in T. congolense infected cattle. Moderate lymph node fibrosis and atrophy were observed. Wellde et al., (1974) found phagocytized and degenerating forms of trypanosomes in the brain, heart and lung smears and many plasma cells were present in the

spleen and lymph node smears. Macrophages from these sites contained large amounts of yellowish brown pigment.

Erythrophagocytosis and increased haemosiderin deposition in the reticuloendothelial system have also been observed in rabbits with T. brucei infections (Boycott and Jones-Price, 1913) in rats with T. brucei (Jennings et al., 1974, Murray et al., 1974), in sheep with T. vivax (Isoun and Anosa, 1975) and T. congolense infections (MacKenzie and Cruickshank, 1974) and in pigs with T. simiae infections ~~(Murray et al., 1974)~~.

Blood Chemistry:

The search by many early researchers to determine the mechanism by which trypanosomes causes injury and death to the host centred around disturbances in carbohydrate metabolism. Early investigators held that death in trypanosomiasis was due to hypoglycemia (French, 1938b; Fiennes, 1954). It has now been shown that hypoglycemia is not a primary cause of death in bovine trypanosomiasis as Fiennes (1970) and Wellde et al., (1974) reported relatively constant serum glucose. A hypoglycemic state may develop just prior to death or at the peak of an anaemic crisis.

Studies of other blood chemical parameters are inconclusive (French, 1938a-f). There may be no significant

change in blood urea nitrogen although serum non-protein nitrogen may be elevated terminally or concomitantly with anaemic crises (French, 1938 d, e; Fiennes et al., 1946). Recently, Wellde et al., (1974) observed that soon after infection, blood urea nitrogen rose to a small or moderate degree over those of pre-infection values. Lower values were recorded in animals surviving for longer periods. Fiennes (1946) reported positive indirect Van den Bergh reaction at times of crises and in moribund animals. Wellde et al., (1974) recorded an elevated total bilirubin early in infection. In chronically infected cows bilirubin was normal. No positive direct Van den Bergh reaction has been reported in bovine trypanosomiasis. Increased blood lactic acid levels have been recorded at premortal stages or near crises (French, 1938a). Blood cholesterol followed erythrocyte levels (Fiennes, 1946). Creatinine was normal early in infection but tended to be slightly lower in chronically infected animals (Wellde et al., 1974).

There have been limited studies of blood electrolyte changes in cattle with trypanosomiasis. French (1938 b,f) reported elevated serum sodium and chloride at the time of anaemic crises. The increase in serum sodium and chloride was believed to be due to the increased proportion

of plasma in infected animals. French (1938) concluded from his studies that the "effect on sodium and chloride metabolism appears to depend upon the level of intake: an adequate consumption is followed by retention but a negative balance results from a low intake". Serum potassium was decreased. Calcium levels tended to be low at times of relapse. Serum inorganic phosphate fell gradually in adult cattle but remained within the normal range in calves (Fiennes, 1970). Serum magnesium was unaffected by the disease except in crisis when levels tended to be low (French, 1938 b). The results of metabolism studies by French suggested that trypanosomiasis was attended by acidosis.

Changes in total plasma proteins in bovine trypanosome infections are inconstant. Low plasma protein values have been reported by several workers (Fiennes, 1954; Godfrey et al., 1968; Naylor, 1971 b; Wellde et al., 1974). Although total plasma proteins may remain unchanged, albumin decreased and there was a corresponding increase in gamma globulins. No significant changes have been observed in plasma fibrinogen values.

Very little information has been published on urine or serum enzyme findings in trypanosomiasis. Urobilin has been found in the urine on rare occasions when the

animal was in extremis (Fiennes, 1954). Wellde et al., (1974) observed an early downward trend in serum glutamic oxaloacetic transaminase (SGOT) followed by stable concentrations. Gray (1963) investigated serum transaminase levels in cattle and sheep with T. vivax infection. Serum glutamic pyruvate transaminase (SGPT) increased and varied with the number of trypanosomes in peripheral blood. Only small increases of SGOT activity occurred. It was concluded that the abnormal serum transaminase activity probably resulted from the destruction of trypanosomes and not from pathological effects of the parasites on the tissue of the host. Reynolds et al., (1973) observed that both sorbitol dehydrogenase (SDH) and glutamate dehydrogenase (GLDH) decreased in T. vivax infected cattle. The decrease was related to the parasitaemia in the peripheral blood. No evidence was found for changes in activity of liver-specific enzymes in serum during non-lethal infection of T. vivax in cattle.

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Table 1: Iron Metabolism In Various Disease States*

| Disease | Serum Iron | Unbound Iron-binding capacity | B.M. Iron Stores | Transfer rate | R.B.C. Iron Incorporatio |
|---|---|---|---|---|---|
| Microcytic hypochromic Anaemias | | | | | |
| Iron deficiency | Decrease | Increase | Decrease | Increase | Increase |
| Chronic Inflammation | Decrease | Decrease | Normal | Decrease | Decrease |
| Pyridoxine Responsive | Increase | Normal | Increase | Decrease | Decrease |
| Macrocytic Anaemia | | | | | |
| Nutritional, Malabsorptive | Increase | Normal | Increase | Decrease | Decrease |
| Haemolytic Anaemia | Increase | Decrease | Increase | Increase | Increase |
| Refractory Anaemia | Increase | Decrease | Increase | Decrease | Decrease |
| Iron overload | Increase | Decrease | Increase | Decrease | Decrease |
| Acute liver disease | Increase | Decrease | Increase | Increase | Increase |
| Hypoproteimia | Decrease | Decrease | | | |
| Late pregnancy | Decrease | Increase | Decrease | Normal | Normal |
| Endocrinopathy (hypothyroidism) | Decrease | | | Decrease | Decrease |

* From Kaneko (1970)

Table 2: Comparison of means and standard deviations of SI, UIBC, TIBC and percentage saturation in adult cattle.

| No. of Animals | Sex | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC | Reference |
|---|---|---|---|---|---|---|
| 5 | Males | 142.4 ± 22.1 | 235.2* | 377.6 ± 34.9 | 38.3 ± 3.9 | Planas and de Castro, 1960 |
| 8 | Females | 177.0 ± 4.7 | 189.7* | 366.7 ± 34.0 | 32.2 ± 4.2 | " |
| - | - | 97.0 ± 29.0 | 131.0 ± 36.0 | 288.0 ± 21.0 | 33.6* | Kolb, 1959 |
| 20 | - | 102.0 ± 6.0 | 266.0* | 368.0 ± 13.0 | 27.7* | Planas, 1963 |
| 18 | - | 150.0 ± 17.2 | 256.1* | 406.1 ± 31.7 | 37.2 + 5.4 | Tartour, 1973 |

* Calculated from available data.

Table 3: The relative prevalence of *T. vivax* and *T. congolense* in the former Zaria Province (mixed infections are excluded).

| | 1955-56[x)] | 1964-65[xx)] | 1967-71[xxx)] |
|---|---|---|---|
| Total no of thick smears examined | 1836 | 806 | 712 |
| Total no. of "positive" smears | 17.5% | 26% | 23% |
| *T. vivax* | 49.5% | 35% | 37.8% |
| *T. congolense* | 47.8% | 65% | 58.5% |

x) Glover (1965)

xx) Folkers and Jones-Davies (1966)

xxx) Ilemobade (1971)

## II: THE BLOOD PICTURE OF WHITE FULANI (ZEBU) AND WHITE FULANI/FRIESIAN (CROSS-FRIESIAN) CATTLE

## INTRODUCTION

The blood picture of Nigerian White Fulani (Zebu) and White Fulani/Friesian crossbred (Cross-Friesian) cattle is of interest for intrinsic and comparative reasons. Haematologic parameters of many breeds of cattle in many countries have been evaluated. Many of these parameters are known to be affected by such factors as age, breed, sex, seasonal variation, lactation and pregnancy (Schalm, 1965).

Little information is available on the blood picture of Nigerian breeds of cattle. Where such information is available, it usually deals with few of the more commonly measured blood parameters of clinical significance. The blood picture of Zebu and N'Dama breeds of cattle in Nigeria has been evaluated and breed and sex differences have been established (Oduye and Okunaiya, 1971). This study was undertaken to establish within broad limits, some of the normal blood values in Zebu and Cross-Friesian cattle.

## MATERIALS AND METHODS

Cattle utilized in the study were Zebus and Cross-Friesians at Shika Research Station as well as native-owned

Zebu cattle. Because of marked differences in feeding, management and husbandry practices between native-owned Zebu cattle and those at Shika Research Station, these two groups have been treated separately. All animals were examined for the presence of blood parasites by the staff of the Department of Veterinary Parasitology at Ahmadu Bello University. Blood samples were harvested during the wet and dry seasons. Dry season sampling was done in March, April and May while wet season samples were taken in August and September 1971. The Shika animals examined included calves, young bulls, suckling cows, pregnant cows and milk cows.

There were few young native Zebu cattle sampled because of the unwillingness of Fulani herdsmen to permit handling of their young animals.

Animals at Shika Research Station were grazed on sown pasture and supplemented with concentrates such as guinea corn, linted cotton seed and groundnut cake during the wet season. During the dry season, hay, maize, elephant grass and gamba grass silage were fed. Salt, calcium, phosphorus, and trace minerals were provided free choice (I.A.R. Guide to Shika Research Station, 1968-1969). The native-owned Zebu cattle were managed under traditional husbandry practices.

Blood samples of 5 ml. were drawn from the jugular vein, using about 4 mg. of disodium salt of ethylene diamine tetraacetic acid (EDTA) as anticoagulant. Blood smears were stained with Wright's stain. Thoma pipettes giving 1:200 and 1:20 dilutions were used for erythrocyte and leukocyte counts respectively. Hayem's fluid and Gower's fluid were the diluents for leukocyte and erythrocyte enumerations respectively. Improved ruling Newbauer haemocytometers were used for erythrocyte and leukocyte counts. Haemoglobin (Hb) was determined by the cyanmethemoglobin method on the Beckman D. B. Spectrophotometer model 1402 at a wavelength of 540 mu. Packed cell volume (PCV) was determined by the microhaematocrit method using the international microhaematocrit centrifuge. The leukocyte (WBC) differential was based on an evaluation of 200 cells. Absolute values for WBC differential, mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) were calculated.

## RESULTS

The data accumulated were analyzed and the results presented in Tables,1, 2, and 3.

Seasonal Variations within Breed:

Significant differences ($P < .01$) were observed in some of the haematologic parameters of Cross-Friesian cattle between the wet and dry seasons. WBC, Hb and MCH values were higher in the wet season (Table 1). Native Zebu cattle also showed significant differences ($P < .01$) in some of the blood values recorded. The WBC was higher in the wet season while the MCHC was lower.

Zebu cattle at Shika exhibited significant seasonal differences ($P < .01$) in haematologic values other than RBC and MCHC. WBC, Hb, PCV, MCV and MCH were higher during the wet season. All three categories of animals investigated had significantly ($P < .01$) higher WBC values in the wet season.

Seasonal Variations Between Breeds:

Significant differences ($P < .01$) were observed in some of the haematologic parameters of all the categories of animals under investigation. Shika Zebu cattle had higher RBC, PCV and Hb values than Cross-Friesian and native Zebu cattle during the wet and dry seasons. Native Zebu cattle had the lowest RBC, PCV and Hb values of all the groups studied.

The results are also summarized by age groups (Table 3). There appears to be a trend to increasing Hb and PCV with increase in age. The leukocyte values appear to decrease with increase in age.

## DISCUSSION

Clinical haematological studies can be a great help to the veterinarian in diagnosis, treatment and prognosis in many disease conditions (Benjamin, 1961; Coles, 1967). Haematologic interpretation is more meaningful when normal values for a given area are established. The report provides an approach to normal blood values in three categories of cattle in Nigeria.

Normal blood values in cattle have been reported by various authors from many parts of the world (Schalm, 1965). The mean RBC, PCV and Hb values in Cross-Friesian and Shika Zebu cattle presented here are well within the accepted normal values as reported in many breeds of cattle (Schalm, 1965). In contrast, native Zebu cattle had mean ~~PCV~~ Hb and ~~Hb~~ PCV values of 9.3 gm/dl. and 28 per cent respectively. These values are well below the mean values reported for other breeds of cattle in temperate

climates (Schalm, 1965). It is of interest to note that the haematological parameters in native Zebu cattle reported here bear close similarity to the values reported for Zebu cattle at the University of Ibadan (Oduye and Okunaiya, 1971). The native Zebu cattle had consistently lower PCV and Hb values than the cattle at Shika Research Farm. It is tempting to postulate that these differences may be attributable in part to the differences in nutrition and husbandry standards.

A seasonal anaemia has been reported in young Zebu cattle in Nigeria (Garner and Unsworth, 1953). The blood Hb content reportedly reached the low average value of 6.1 to 6.5 gm/dl. during July, August, September and October and subsequently increased to an average value of 9.6 gm during March. The aetiology of the anaemia was undetermined, however. This phenomenon has not been observed in this study. More extensive studies are needed to establish the prevalence and aetiology of this syndrome in Zebu cattle.

## SUMMARY

Haematological parameters in three categories of Nigerian cattle were determined. Native-owned Zebu cattle had the lowest PCV and Hb values. Cross-Friesian cattle had lower PCV and Hb values than Zebu cattle under the same husbandry and management practices. Seasonal variations between and within the categories of cattle investigated are reported.

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Table 1: The means, standard deviations and ranges of selected haematological values in White Fulani, White Fulani/Friesian cross and native owned White Fulani cattle during wet and dry seasons - All animals.

| Measurement | DRY SEASON | | | WET SEASON | | |
|---|---|---|---|---|---|---|
| | White Fulani | White Fulani/ Friesian Cross | Native White Fulani | White Fulani | White Fulani/ Friesian Cross | Native White Fulani |
| No. of Animals | 117 | 145 | 49 | 135 | 155 | 53 |
| Mean age (Mo) | 54 | 24 | Unknown | 63 | 27 | Unknown |
| RBC x $10^6$/$mm^3$ | 7.2±1.1 | 6.7±1.3 | 6.0±1.6 | 7.4±1.2 | 6.8±1.2 | 6.1±1.5 |
| | 4.7±9.9 | 3.5-10.0 | 3.8-9.1 | 3.7-9.9 | 4.2-9.1 | 3.6-9.2 |
| WBC x $10^3$/$mm^3$ | 9.9±2.5 | 9.9±2.9 | 9.8±3.6 | 10.8±3.1 | 11.0±3.2 | 13.9±1.4 |
| | 3.7-15.5 | 5.5-17.8 | 6.9-18.6 | 3.4-20.7 | 5.6-21.7 | 3.0-20.0 |
| Hb Gm/ dl | 11.3±1.5 | 10.4±1.5 | 9.4±1.7 | 12.7±2.5 | 11.1±1.4 | 9.2±1.9 |
| | 8.1-14.8 | 5.8-13.6 | 6.4-12.7 | 8.9-17.5 | 8.6-15.8 | 6.0-13.1 |
| PCV % | 33.3±4.7 | 31.2±4.6 | 27.6±4.7 | 36.5±4.8 | 31.8±4.2 | 28.3±5.5 |
| | 20.0-45.0 | 19.0-41.7 | 22 - 37 | 25.4-46.0 | 22.6-44.9 | 19.5-39 |
| MCV $u^3$ | 47.0±6.8 | 48.1±8.4 | 47.1±7.8 | 50.5±9.4 | 47.5±9.1 | 47.5±10 |
| | 27.6-67.7 | 31.5-75.3 | 37.4-68.3 | 32.0-84.7 | 31.2-70.1 | 36.4-68.2 |
| MCH uug | 16.0±2.3 | 15.9±2.9 | 15.8±2.4 | 17.0±3.4 | 16.6±3.2 | 15.3±3.3 |
| | 19.8-23.9 | 10.6-24.5 | 11.0-22.2 | 11.4-29.7 | 11.5-24.4 | 12.2-20.7 |
| MCHC % | 34.1±1.7 | 33.1±2.2 | 33.8±2.1 | 34.5±2.0 | 34.9±2.0 | 31.8±5.3 |
| | 28.2-39.9 | 28.9-36.3 | 23.5-39.1 | 30.4-41.1 | 29.9-41.3 | 29.1-39.1 |

Table 2: The means and standard deviations of WBC differential counts of White Fulani, White Fulani/Friesian and native White Fulani cattle during wet and dry seasons.



| | | | DIFFERENTIAL COUNT IN ABSOLUTE VALUES x $10^3$/cm | | | | | DIFFERENTIAL COUNT IN PERCENTAGES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Breed | Season | No.of Anims | Total WBC | Neut. | Lymph | Mono | Eosino | Neut. | Lymph | Mono | Eosino |
| WF | Dry | 98 | 10.1±2.5 | 2.4± .9 | 6.6±2.0 | .3±.2 | .8±.5 | 23.9±7.9 | 64.9±10.0 | 2.9±1.4 | 8.3±4.9 |
| CF | Dry | 59 | 9.4±2.9 | 2.5±1.1 | 6.0±2.2 | .2±.5 | .7±.5 | 25.2±6.6 | 64.2± 7.8 | 2.7±1.3 | 7.9±4.8 |
| NWF | Dry | 36 | 9.0±3.0 | 1.9± .8 | 5.7±2.3 | .2±.1 | 1.2±.9 | 21.0±7.1 | 62.3±10 | 2.5±1.5 | 14.2±8.8 |
| WF | Wet | 111 | 11.2±3.0 | 2.9±1.1 | 6.8±2.2 | .4±.2 | 1.1±.7 | 26.4±7.3 | 59.6±9.8 | 3.4±1.9 | 10.6±5.6 |
| CF | Wet | 126 | 10.9±2.9 | 2.8±1.2 | 6.8±2.3 | .4±.3 | 1.0±.7 | 25.3±7.8 | 63.4±10.6 | 3.3±2.5 | 8.0±6.6 |
| NWF | Wet | 33 | 13.4±2.8 | 2.9±1.4 | 8.8±2.1 | .5±.3 | 1.2±.6 | 21.0±9.5 | 66.3± 9.7 | 3.7±2.2 | 9.0±4.6 |

WF = White Fulani

CF = Cross-Friesians

NWF = Native White Fulani

Table 3: The means and standard deviations of selected haematological values of Zebu and Zebu/Friesian cattle during wet and dry season - in age groups.



| Season | Breed | No.of Anims. | Range in Age(Mo.) | Mean age (months) | RBC x $10^6$/cmm | WBC x $10^3$/cmm | Hb gm/dl | PCV % |
|---|---|---|---|---|---|---|---|---|
| Dry | Zebu | 15 | 3-12 | 9 | 8.1±0.9 | 10.1±2.9 | 11.6±1.6 | 35.7±5.4 |
| " | " | 28 | 13-24 | 21 | 6.8±0.9 | 10.6±2.4 | 10.3±1.0 | 30.0±3.1 |
| " | " | 15 | 25-36 | 32 | 7.6±1.3 | 10.6±2.7 | 11.4±1.7 | 32.9±5.0 |
| " | " | 15 | 37-48 | 44 | 7.4±0.9 | 9.4±2.4 | 11.6±1.5 | 34.5±4.2 |
| " | " | 9 | 49-72 | 65 | 6.2±1.0 | 9.3±3.2 | 11.2±1.2 | 32.5±6.6 |
| " | " | 35 | 73-164 | 109 | 7.1±0.9 | 9.3±2.2 | 11.9±1.4 | 34.8±4.4 |
| Dry | Zebu/ Friesian | 50 | 3-12 | 8 | 7.5±1.4 | 10.5±3.0 | 10.2±1.4 | 31.4±4.4 |
| " | " | 40 | 13-24 | 19 | 6.4±1.1 | 10.5±3.0 | 9.9±1.6 | 29.3±4.4 |
| " | " | 30 | 25-36 | 31 | 6.0±0.8 | 9.1±2.7 | 10.5±1.4 | 30.7±4.1 |
| " | " | 11 | 37-48 | 46 | 6.3±0.9 | 8.3±1.9 | 11.5±1.1 | 33.8±5.4 |
| " | " | 14 | 49-84 | 59 | 6.4±1.1 | 8.5±2.6 | 11.6±1.1 | 35.1±3.5 |
| Wet | Zebu | 10 | 3-12 | 8 | 7.7±1.6 | 10.9±3.4 | 10.7±1.6 | 30.7±5.7 |
| " | " | 14 | 13-24 | 19 | 7.3±1.0 | 11.4±1.8 | 11.2±1.2 | 32.6±3.6 |
| " | " | 18 | 25-36 | 29 | 7.8±1.1 | 12.4±2.7 | 11.8±1.4 | 33.8±4.0 |
| " | " | 22 | 37-48 | 43 | 7.9±1.3 | 11.1±2.4 | 13.2±4.6 | 38.4±3.9 |
| " | " | 27 | 49-72 | 61 | 7.5±0.9 | 10.9±2.6 | 13.0±1.5 | 38.5±3.2 |
| " | " | 44 | 73-164 | 116 | 7.0±1.2 | 9.7±3.8 | 13.0±1.5 | 38.0±4.1 |
| Wet | Zebu/ Friesian | 43 | 3-12 | 8 | 7.8±0.9 | 12.4±3.5 | 10.5±1.1 | 30.2±3.3 |
| " | " | 53 | 13-24 | 18 | 6.7±1.1 | 11.3±2.7 | 10.6±1.4 | 30.6±4.1 |
| " | " | 19 | 25-36 | 31 | 6.6±1.0 | 11.4±3.6 | 11.7±0.9 | 33.5±2.4 |
| " | " | 11 | 37-48 | 40 | 6.0±0.9 | 9.2±2.0 | 11.2±1.3 | 32.1±3.8 |
| " | " | 29 | 49-84 | 64 | 6.3±1.1 | 8.6±2.0 | 12.3±1.5 | 35.0±4.5 |

## III: THE BLOOD PICTURE OF WHITE FULANI (ZEBU) AND WHITE FULANI/FRIESIAN (CROSS-FRIESIAN) DAIRY COWS

## INTRODUCTION

The problem of adequate milk supply to urban areas in Nigeria has occupied the attention of the Agricultural and Veterinary Departments of Nigeria for some time. In the early 1950's, efforts aimed at selective breeding of Zebu cattle for milk production were shelved following the realization that the process would be too slow (Armour et al., 1961). A program of cross breeding of indigenous cows with British Friesian bulls was initiated. The cross breeding techniques used and the performance of these Cross-Friesians have been reported (Byers et al., 1952; Armour and Sainsbury, 1956; Armour et al., 1961). Experience at Federal Veterinary Research Institute, Vom and at Shika Research Station shows conclusively that Cross-Friesian cows are superior to Zebu cows as milk producing animals (Armour et al., 1961; I.A.R. Guide to Shika, 1968-69; Knudsen and Sohael, 1970). These Cross-Friesian cows are expected to play a vital role in the efforts to increase milk production for the urban areas. The effectiveness of veterinary care for these animals may be hindered by the lack of haematological data that could be used as an aid in the clinical evaluation of disease conditions. This paper reports the haematologic parameters in clinically healthy high milk yielding Zebu and Cross-Friesian cows.

## MATERIALS AND METHODS

This work was carried out at Shika Research Station. The animals were pure bred Zebu and Cross-Friesian cows in the dairy herd. This herd consists of the highest yielding cows on which accurate milk production records are kept. The cows are rotationally grazed on sown pasture during the wet season and supplemented with concentrates such as guinea corn, linted cottonseed and groundnut cake. In the dry season, they are fed 30-40 pounds of silage and supplemented with concentrates. Water, salt, calcium, phosphorus and trace minerals are fed free choice. All the animals are machine milked. Blood samples were taken after the usual morning milking. The haematological techniques used were the same as those described in a previous communication (Saror and Coles, 1973).

## RESULTS

The data were analyzed and the results are presented in Table 1.

Except for mean corpuscular haemoglobin concentration (MCHC) there was no significant seasonal variation in the haematologic parameters of Zebu cattle. The MCHC in Zebu cattle was higher in the wet season. The Cross-Friesians had significantly higher leukocyte and MCHC values during the wet season.

Zebu cows had significantly ($P < .01$) higher erythrocyte (RBC) leukocyte (WBC) and haemoglobin (Hb) values than Cross-Friesians in the dry season and higher RBC, Hb values in the wet season. There were no significant seasonal differences in the WBC differential values in Zebu and Cross-Friesian cows.

## DISCUSSION

Zebu cows in this study had mean Hb and packed cell volume (PCV) values of 12.8 gm/dl and 36.6 per cent respectively.

Cross-Friesians had mean blood Hb of 11.6 gm and PCV of 34.1 per cent. These values compare favourably with those reported in other dairy breeds (Schalm, 1965).

It should be stressed, however, that these data were obtained for cows under a good level of disease control, feeding and management. The Cross-Friesians in this study had lower mean blood Hb content than the Zebu cattle. However, they produce on the average 200 per cent more milk per lactation than pure Zebu cows (I.A.R. Guide to Shika 1968-69). There is no apparent relationship between blood Hb level and milk production. Hb values in dairy cows can be used as an index of the nutritional status of the animal with respect to iron, copper and

cobalt (Byers et al., 1952). Since the presence or absence of disease is often first mirrored in the haematologic values of an animal, the establishment of baseline values for particular dairy herds should prove beneficial in clinical evaluation of blood samples from diseased animals.

## SUMMARY

RBC, PCV, Hb and WBC were measured and MCV, MCH, MCH were calculated in blood samples from 33 pure-Zebu cows in lactation in the wet and dry seasons. Cross-Zebu/Friesian Friesians had lower Hb content than pure Zebu cows in both wet and dry seasons. Haematologic parameters in both groups did not show significant seasonal variations.

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Table 1: The means and standard deviations of selected haematological values in white Fulani and white Fulani/Friesian dairy cows during wet and dry seasons.

| | White Fulani | | White Fulani/ Friesian Cross | |
|---|---|---|---|---|
| | Dry Season | Wet Season | Dry Season | Wet Season |
| No. of Animals | 23 | 10 | 15 | 23 |
| Mean age (Mo) | 90 | 95 | 51 | 51 |
| RBC x $10^6$/cm | 7.2±0.9 | 6.8±1.4 | 6.2±1.0 | 5.9±0.9 |
| WBC x $10^3$/dl | 8.9±1.9 | 10.6±4.0 | 7.4±1.5 | 8.9±2.0 |
| Hb in Gm/dl | 12.4±1.1 | 13.3±2.2 | 11.5±1.3 | 11.8±1.2 |
| PCV % | 36.6±3.5 | 36.5±5.5 | 34.7±3.8 | 33.5±3.5 |
| MCV - $u^3$ | 51.2±6.8 | 55.3±13.2 | 57.2±6.4 | 57.0±6.7 |
| MCH - uug | 17.5±2.4 | 19.7±5.1 | 18.7±2.0 | 20.2±2.9 |
| MCHC - % | 33.9±1.2 | 36.1±2.2 | 33.0±0.9 | 35.2±1.9 |
| WBC Differential | | | | |
| Neutrophils | 25.9±5.4 | 29.0±0.9 | 28.0±5.9 | 28.3±6.5 |
| Lymphocytes | 62.8±7.5 | 57.0±10.9 | 60.9±6.5 | 59.3±8.5 |
| Monocytes | 2.6±1.4 | 3.0±1.4 | 2.8±1.2 | 3.8±3.7 |
| Eosinophils | 8.7±6.8 | 11.0±4.1 | 8.3±4.2 | 8.6±4.1 |
| Basophils | 0 | 0 | 0 | 0 |

# IV: HAEMATOLOGY OF NIGERIAN ZEBU CATTLE UNDER NATIVE HUSBANDRY PRACTICES

## INTRODUCTION

The blood picture of Nigerian Zebu cattle under native husbandry practices is of interest for intrinsic and extrinsic reasons. Haematological examination is an essential procedure for the diagnosis of many protozoan infections, so prevalent in cattle and other species in tropical and subtropical countries.

Haematologic parameters of many breeds of cattle in temperate countries have been determined. Many of these parameters are known to be influenced by factors such as age, breed, sex, seasonal variations, lactation and pregnancy (Schalm, 1965). Although it could be expected that haematologic parameters of cattle in temperate zones could be different from blood values of indigenous cattle under native husbandry practices; these temperate values (easily found in textbooks) have long been used in tropical areas for interpretation of clinical data. This could lead to inaccurate diagnosis. The need to establish baseline values for haematologic and biochemical parameters in native cattle under local conditions is thus self evident.

Oduye and Okunaiya (1971) reported on the haematologic parameters of Zebu and N'Dama breeds of cattle in southern

Nigeria and established breed and sex differences. Saror and Coles (1973a) examined the influence of age, season and management practices on the haematologic parameters of native-owned Zebu cattle, Zebu and Zebu/Friesian cross cattle under improved husbandry and management practices in Northern Nigeria. Seasonal and age differences were established. Haematologic parameters of native-owned and managed Zebu cattle differed significantly from those of Zebu cattle under modern husbandry practices (Table 1).

This study was undertaken to:

(a) reassess the influence of age on haematologic parameters of Zebu cattle under semi-improved native husbandry practices.

(b) evaluate the influence of seasonal changes in the blood picture of adult Zebu cattle under semi-improved native husbandry practices.

## MATERIALS AND METHODS

Two hundred and twenty-two Zebu cattle varying in age from birth to over 10 years were utilized. Age of animals was estimated from the teeth (Sisson and Grossman, 1953). Cattle sampled included 54 calves from birth to 4 weeks of age; 70 calves 5 weeks to approximately 1 year;

44 heifers approximately 1 to 3 years of age and 54 adult non-pregnant cattle. All animals were at the Galambi ranch, 19 miles south-east of Bauchi town. Management and husbandry practices on this ranch have been described (Saror and Coles, 1975).

Blood samples were obtained via venipuncture into vacutainer tubes containing disodium salt of ethylene diamine tetra-acetic acid (EDTA) as anticoagulant. Blood samples were transported to Ahmadu Bello University, Zaria under chilled conditions. The adult cows were sampled between January/February; May/June and September/October, 1974.

Haemoglobin (Hb), packed cell volume (PCV), total erythrocytes (RBC) and total leukocytes (WBC) were determined using routine laboratory procedures (Saror and Coles, 1973a). Thin blood smears were stained with Giemsa's stain for differential leukocyte counts; these were based on 100 cells.

## RESULTS

Means and standard deviations of blood constituents according to age are presented in Table 2. Individual cow data are presented in appendix 1. The PCV, Hb and RBC of calves from birth to 4 weeks of age were

significantly higher ($P < .01$) than cattle in other age group. Calves 1 month to 1 year old had significantly lower ($P < .01$) PCV, Hb and RBC than calves from birth to 4 weeks of age but sifnificantly higher ($P < .01$) values than older cattle. There was no significant difference in PCV, Hb and RBC between heifers 1 to 3 years old and adult cattle.

Calves from birth to 4 weeks old had lower total leukocyte counts than older cattle. One week old calves had lower total leukocytes than older calves. A relative neutrophilia and lymphopenia was observed in one week old calves (Table 3). There was no significant difference in the percentage distribution of leukocytes in cattle 1 month to 12 months and 1 year to 3 years old. Adult cattle had significantly higher ($P < .01$) eosinophil counts than younger cattle.

Blood constituents of adult non-pregnant Zebu cattle in the course of a year are presented in Table 4. No significant differences were observed in the blood profile of these animals over the period of study.

## DISCUSSION

Haematologic changes associated with age have been documented in many breeds of cattle (Greatorex, 1954,

1957; Holman, 1956; Wingfield and Tumbleson, 1973). Similar age related variations have been reported in Zebu cattle (Garner and Unsworth, 1953; Oduye and Okunaiya, 1971; Saror and Coles, 1973a) and Zebu/Friesian cross cattle (Duckworth and Rattray, 1948; Saror and Coles, 1973b).

The results of this study confirmed previous observations that in Zebu cattle (as in other breeds of cattle) Hb, PCV and RBC values declined with advancing age. The finding of relative neutrophilia in one week old calves is in agreement with previous observations by Schalm (1965). After 12 months of age the haematologic parameters were indistinguishable with those of adult cattle. Although leukocyte counts reported here were higher than those observed in other breeds of cattle; the percentage distribution of leukocytes was strikingly similar (Schalm, 1965; Oduye and Okunaiya, 1971; Saror and Coles, 1973a). The reason for the higher total leukocyte counts could be attributed, partly to excitement and struggling at times of sampling.

Mean values for Hb and PCV in adult non-pregnant animals were in close agreement with previous observations in adult Zebu cattle (Smith, 1959; Oduye and Okunaiya, 1971; Saror and Coles, 1973a). They were however, lower

than normal values in white Fulani (Zebu) cattle under improved management and husbandry practices (Saror and Coles, 1973b) and other native breeds such as N'Dama (Oduye and Okunaiya, 1971). Haemoglobin and PCV values in Zebu cattle under semi-improved native husbandry were lower than those reported in temperate breeds (Holman, 1955; Schalm, 1965) and Holstein cattle raised in the tropics (Saror and Coles, 1973a). It is postulated that the lower Hb and PCV values encountered in Zebu cattle under native husbandry practices is not a breed characteristic but derives from the lower nutritional status and stressing husbandry methods of native herdsmen.

There were no significant changes in blood constituents of Zebu cattle under native husbandry practices that could be attributed to seasonal influence. Similar observations have been recorded in Zebu and other breeds of cattle (Schalm, 1965; Saror and Coles, 1973a).

## SUMMARY

The blood constituents of Zebu cattle from birth to over 10 years of age were determined. The cattle were maintained under native husbandry practices. The Hb, PCV and total RBCs decreased with age from birth to approximately 1 year of age. Thereafter, Hb and PCV were not

significantly different from values found in adult cattle. Adult Zebu cattle under native husbandry practices had lower PCV and Hb than similar cattle maintained under improved management and husbandry conditions or adult cattle in temperate zones. The lower PCV and Hb in native cattle were attributed to lower nutritional status and stress prevalent among Zebu cattle under native husbandry practices.

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Table 1: Means of haematologic parameters of Zebu cattle under native and improved husbandry practices.

| Husbandry practice. | No. of Animals | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC x $10^3$ | WBC Differential | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Neut % | Lym. % | Eo % | Mono % | |
| Native | 40 | 32.8 | 9.98 | 6.21 | 11.22 | 31 | 50 | 13 | 6 | Smith, 1959 x |
| | 49 | 27.6 | 9.4 | 6.0 | 9.8 | 22 | 62 | 14 | 2 | Saror & Coles 1973a + |
| | 53 | 28.3 | 8.2 | 6.1 | 13.9 | 22 | 66 | 9 | 3 | Ibid. * (1973a) |
| | 150 | 30.1 | 9.0 | N D | 9.9 | 20 | 67 | 9 | 4 | Oduye & Okunaiya (1971) x |
| Improved | 117 | 33.3 | 11.3 | 7.2 | 9.9 | 24 | 65 | 8 | 3 | Saror & Coles (1973a) + |
| | 135 | 36.5 | 12.7 | 7.4 | 10.8 | 26 | 60 | 11 | 3 | Ibid. (1973a) * |
| | 23 | 36.6 | 12.4 | 7.4 | 8.9 | 26 | 63 | 8 | 3 | Saror & Coles (1973b) + |

x = Semi improved husbandry practice.

\+ = Dry Season.

* = Wet Season.

N D = Not determined.

Table 2: Means and standard deviations of haematologic parameters in Zebu cattle according to age groups.

| No. of Animals | Age Group | PCV % | Hb Gm/dl | RBC x $10^6/mm^3$ | WBC | Lymph % | Segs % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|---|
| 54 | Birth to 4 wks (2.5 weeks)* | 35.2 ± 5.4 | 11.4 ± 1.7 | 9.39 ± 1.76 | 8454 ± 3296 | 71.5 ± 11.8 | 25.8 ± 11.5 | 1.3 ± 1.2 | 1.4 ± 1.4 |
| 70 | 1 month-12mths (6 months)* | 32.5 ± 4.3 | 10.9 ± 1.5 | 8.64 ± 1.88 | 10206 ± 3794 | 73.0 ± 10.0 | 21.2 ± 9.0 | 4.4 ± 4.2 | 1.4 ± 1.5 |
| 44 | 1 yr - 3 yrs (1.8 yrs)* | 28.5 ± 2.5 | 9.1 ± 0.9 | 7.47 ± 1.06 | 14241 ± 3700 | 70.4 ± 7.8 | 22.8 ± 6.7 | 5.8 ± 3.6 | 1.0 ± 1.4 |
| 54 | Over 3 years | 30.0 ± 3.0 | 9.9 ± 1.1 | 6.23 ± 1.08 | 11529 ± 2947 | 55.1 ± 12.4 | 26.8 ± 10.8 | 15.6 ± 7.0 | 2.5 ± 2.0 |

* = Mean age

Table 3: Total and differential leukocyte counts in 54 Calves from birth to 4 weeks.

| Age (Weeks) | No. of Calves | Total WBC | WBC Differential - Absolute counts | | | |
|---|---|---|---|---|---|---|
| | | | Lymph | Neut | Eo | Mono |
| 1 | 12 | 6580 ± 3266 | 3875 ± 1528 | 2541 ± 2014 | 91 ± 82 | 73 ± 69 |
| 2 | 15 | 8957 ± 2039 | 6436 ± 2229 | 2229 ± 1151 | 123 ± 98 | 171 ± 128 |
| 3 | 13 | 8101 ± 3212 | 5961 ± 2602 | 1938 ± 1154 | 122 ± 129 | 80 ± 71 |
| 4 | 14 | 9928 ± 3778 | 8022 ± 3363 | 1746 ± 818 | 65 ± 83 | 95 ± 171 |

Table 4: Means and standard deviations of haematologic parameters in apparently healthy female non-pregnant adult Zebu cattle in the course of one year.

| Time of Year | No. of Animals | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | Lymph % | Segs % | Eos % | Mono % |
|---|---|---|---|---|---|---|---|---|---|
| Jan - Feb. | 43 * | 30.6 ± 3.5 | 10.2 ± 1.2 | 6.72 ± 1.48 | 10766 ± 4445 | 55.0 ± 10.2 | 27.0 ± 8.8 | 15.0 ± 7.6 | 3.0 ± 2.2 |
| May - June | 42 * | 30.0 ± 3.8 | 10.2 ± 1.4 | 6.03 ± 0.86 | 12888 ± 3497 | 59.4 ± 13.0 | 26.8 ±13.0 | 12.0 ± 6.4 | 1.8 ± 2.8 |
| Sept - Oct. | 54 | 30.0 ± 3.0 | 9.9 ± 1.1 | 6.23 ± 1.08 | 11529 ± 2947 | 55.0 ± 12.4 | 26.9 ±10.8 | 15.6 ± 7.0 | 2.5 ± 2.0 |

* of the 54 studied

# V: DAILY VARIATIONS IN SERUM IRON AND IRON-BINDING CAPACITY IN ZEBU CATTLE

## INTRODUCTION

It is generally recognized that serum iron (SI) and total iron-binding capacity (TIBC) in domestic animals fluctuate from day to day. Such daily variations are influenced by factors such as age, sex, feeding habits, time of sampling and exercise (Obara et al., 1957; Kolb, 1963; Osbaldiston and Griffith, 1972; Tartour, 1973). The extent of daily variations in Zebu cattle has not been reported. The purpose of this investigation was to determine the normal SI and iron-binding capacity of serum as well as their daily variations in Zebu cattle.

## MATERIALS AND METHODS

Ten apparently healthy Zebu cows aged $2\frac{1}{2}$ to 4 years were utilized. The cows were observed for a period of 3 weeks prior to experiment. Faecal samples were examined prior to start of experiment. All animals were treated with thiabendazole[a] for strongyles and were sprayed weekly with 0.05% pfizona[b] to rid them of external parasites.

The cows were housed in pens and fed a mixture of ground guinea corn and linted cotton seed every morning

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[a] Thiabendazole, Merck Sharp and Dohme Ltd; Hoddesdon Herdfordshire, England.

[b] Pfizona, Pfizer, Products, Ltd; PMB 111, Ikeja, Nigeria.

before being taken out to pasture for approximately 7 hours daily. No mineral supplementation was provided. Water was provided ad libitum. The health status of the animals was monitored by daily clinical examination and haematologic evaluation.

Sampling:

Blood samples were obtained via the jugular vein into 10 ml vacutainer tubes[c], allowed to clot at room temperature and then centrifuged[d] at 3500 rpm for 15 minutes. Serum was decanted into iron-free tubes and frozen until analysed. Blood samples for haematologic evaluation were collected into vacutainer tubes containing EDTA as the anticoagulant. Sampling was done daily between 0700 and 0800 hours for a period of 10 days.

Haematological Investigations:

Haemoglobin was determined by the cyanmethaemoglobin procedure, PCV by the microhaematocrit method, erythrocytes (RBC) and total leukocytes (WBC) were enumerated using the improved Neubauer haemocytometer.

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c Jintan Terumo Co. Ltd; Tokyo, Japna.

d International Equipment Co., Needham, Mass., USA.

Chemical Methods:

Serum iron (SI), unbound iron-binding capacity (UIBC) and total iron-binding capacity (TIBC) were determined by the method of O'Malley et al., (1970) using commercial reagent kits[e]. With this method, serum iron, after being disassociated from the iron-transferrin complex, is reduced to a ferrous state and reacted with a colour developing reagent, 2, 4, 6 - tripyridyl-s-triazine (TPTZ). The concentration of iron in serum is directly proportional to the intensity of the developed colour. In the determination of TIBC the iron - TPTZ complex is disassociated by elevating the pH with iron-binding buffer (pH 9). The disassociated iron rebinds with transferrin. A known amount of excess iron is then added to saturate the transferrin. The excess iron reacts with the TPTZ already present to give a colour whose intensity is directly proportional to the excess, unbound iron. The amount of this excess iron substracted from the known amount gives the UIBC. The TIBC equals the sum of UIBC and SI values. Per cent saturation of transferrin was calculated using the formula:

$$\frac{SI}{TIBC} \times 100 = \text{saturation concentration (SC)}$$

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[e] Harleco Serum Iron Kits. Phil. Pa. USA

were observed. The extent of these variations in individual cows was probably influenced by the rate of iron absorption, excretion, and the extent of haematopoiesis. The SI, UIBC, TIBC and SC recorded were in general agreement with previous observations in cattle (Planas and De Castro, 1960; Kolb, 1963; Underwood, 1971; Tartour, 1973).

Diurnal variations in SI occur in man (Hamilton, et al., 1950) and domestic animals (Kolb, 1963; Osbaldiston and Griffith, 1972). The effect of diurnal variations was minimized in this study by collecting blood samples at the same time each day. Osbaldiston and Griffith (1972) observed marked daily variation in SI in normal horses and concluded that except in extreme conditions, SI concentrations had limited value for clinical interpretation. Experimental findings in man (Beutler, 1957; Brown, 1966; Pollycove, 1966) and animals (Blaxter et al., 1957; Hansard and Foote, 1959; Kolb, 1963, Bremner and Reynolds, 1965; Tartour and Idris, 1973) indicated that SI when used in conjunction with other relevant haematologic parameters, may be invaluable in determining the pathogenesis of some anaemias in man and animals.

## SUMMARY

Serum iron, UIBC, TIBC,and SC concentrations were measured daily in 10 cows. Only slight variations in the mean values of the above parameters occurred during the 10 days of observation.

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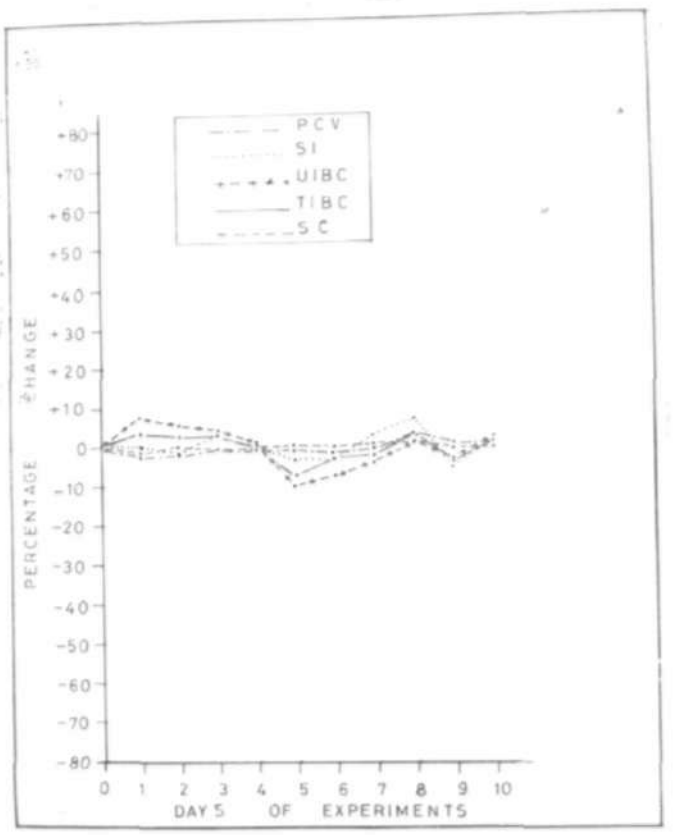
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Table 1: Packed cell volume, Haemoglobin, Leukocyte count, Serum Iron, Iron-binding capacity and percentage saturation of transferrin in individual cows over a 10-day period (Means and ranges).

| Animal No | PCV % | Hb gm/dl | WBC x $10^3$ | SI ug/dl | UIBC ug/dl | TIBC ug/dl | % Saturation |
|---|---|---|---|---|---|---|---|
| 1 | 33.8 (31-35) | 11.4 (10.5-12.2) | 14.6 (11.4-18.4) | 139 (130-155) | 211 (185-155 | 350 (325-390 | 39 (35-40) |
| 2 | 32.2 (30-34) | 10.9 (10-11.2) | 18.8 (13.3-22.8) | 121 (105-132) | 221 (200-240) | 342 (305-377) | 35 (32-39) |
| 3 | 29.1 (28-30) | 9.7 (9.2-10.4) | 14.1 (10.8-16.8) | 98 ( 70-130) | 212 (185-230) | 310 (275-360) | 32 (25-40) |
| 4 | 33.9 (33-35) | 11.3 (10.4-10.5) | 16.0 (11.0-20.1) | 103 ( 85-118) | 210 (145-260) | 313 (255-365) | 33 (26-43) |
| 5 | 28.8 (26-30) | 9.6 (8.6-10.5) | 12.0 (9.3-16.5) | 73 ( 50-95) | 192 (155-265) | 265 (235-315) | 28 (15-38) |
| 6 | 35.4 (34-38) | 11.8 (11.2-12.6) | 10.7 (9.7-12.3) | 151 (110-180) | 192 (145-225) | 343 (305-395) | 44 (32-53) |
| 7 | 29.6 (28-31) | 9.9 (9.4-10.6) | 7.9 (4.2-10.7) | 123 (110-132) | 158 ( 95-220) | 281 (210-345) | 44 (36-54) |
| 8 | 30.4 (29-32) | 10.4 (10-11.2) | 16.3 (12.8-21.3) | 169 (150-185) | 225 (185-250) | 394 (350-435) | 43 (39-48) |
| 9 | 28.4 (26-30) | 9.3 (8.3-10.3) | 20.8 (17.9-22.9) | 177 (150-200) | 200 (155-230) | 377 (329-425) | 47 (41-53) |
| 10 | 34.0 (32-36) | 11.6 (10.5-12.5) | 19.0 (10.2-22.9) | 152 (125-180) | 200 (160-240) | 352 (334-380) | 43 (34-53) |
| All Samples | 32.0 (26-38) | 10.6 (8.3-12.6) | 14.0 (4.2-22.9) | 131 ( 50-200) | 202 ( 95-265) | 333 (210-435) | 39 (15-54) |

Table 2: Mean Daily Values of Packed Cell Volume, Haemoglobin, Total Leukocytes, Serum Iron, Iron-binding Capacity and percentage saturation in ten cows over a 10-day period (Means and range).

| Day of Observation | PCV % | Hb gm/dl | WBC x $10^3$ | SI ug/dl | UIBC ug/dl | TIBC ug/dl | % Saturation |
|---|---|---|---|---|---|---|---|
| 1 | 31.1 (28-34) | 10.5 (9.2-11.3) | 13.0 (5.5-21.2) | 130 (70-185) | 219 (155-255) | 349 (275-435) | 37 (25-52 |
| 2 | 31.0 (28-34) | 10.4 (9.2-11.9) | 14.0 (4.2-20.2) | 129 (75-195) | 214 (180-260) | 343 (2255-380) | 37 (27-51) |
| 3 | 31.4 (28-34) | 10.5 (9.2-11.5) | 16.2 (6.9-22.9) | 135 (50-200) | 209 (145-265) | 344 (255-385) | 39 (16-52) |
| 4 | 31.4 (26-37) | 10.4 (8.5-12.5) | 15.1 (8.2-22.9) | 130 (60-200) | 204 (150-240) | 334 (280-385) | 39 (21-53) |
| 5 | 31.6 (28-35) | 10.5 (9.4-11.8) | 14.9 (9.9-22.9) | 127 (95-175) | 182 (95-205) | 309 (210-377) | 41 (25-55) |
| 6 | 31.8 (29-35) | 10.7 (9.6-11.8) | 14.9 (8.1-24-4) | 127 (65-175) | 187 (130-225) | 314 (250-400) | 40 (25-49) |
| 7 | 31.5 (28-35) | 10.5 (9.0-11.9) | 16.0 (8.5-21.1) | 135 (80-170) | 193 (145-210) | 328 (280-390) | 41 (26-53) |
| 8 | 32.4 (29-38) | 11.0 (9.6-12.5) | 14.9 (8.9-22-3) | 140 (95-195) | 204 (145-250) | 344 (255-425) | 41 (35-46) |
| 9 | 31.9 (26-38) | 10.6 (8.6-12.6) | 15.8 (8.5-22.9) | 124 (75-160) | 195 (100-250) | 319 (215-410) | 39 (32-53) |
| 10 | 31.7 (27-36) | 10.4 (8.3-12.0) | 15.7 (8.0-21.1) | 132 (80-180) | 206 (166-245) | 338 (240-410) | 39 (28-47) |


PCV
SI
UIBC
TIBC
SC
+80
+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
PERCENTAGE CHANGE
0 1 2 3 4 5 6 7 8 9 10
DAYS OF EXPERIMENTS

# VI: VARIATIONS WITH AGE IN SERUM IRON AND IRON-BINDING CAPACITY IN ZEBU CATTLE.

## INTRODUCTION

The influence of age on serum iron (SI) and iron-binding capacity in cattle has been investigated in various parts of the world (Kolb, 1963; Bremner, 1966; Tartour, 1973). Most studies concerned the effect of age on SI concentration in calves. This is understandable as iron deficiency anaemia has been observed in calves under various husbandry practices and geographic areas (Knoop et al., 1935; Blaxter et al., 1957; Kolb, 1963). There have been no reports on the effect of age on SI in Nigerian Zebu cattle. The purpose of this study was to determine the variations, with age, of SI and iron-binding capacity in Nigerian Zebu cattle under semi-native husbandry practices.

## MATERIALS AND METHODS

### Animals:

One hundred and forty-one apparently healthy Zebu cattle from the Galambi ranch varying in age from a few days to 10 years were utilized. The group examined included 34 calves up to 4 weeks of age, 37 calves from 5 weeks to 1 year, 42 heifers from 1 year to 3 years and 28 adult non-pregnant cows. The cattle were maintained at the Galambi ranch located 19 miles south

east of Bauchi town along Dass road. They were attended by local herdsmen under the supervision of a livestock superintendent. New-born calves were suckled by their dams in the mornings and evenings. The non suckling calves, heifers and adult cows were taken out to pasture every day from 9 a.m. to 5 p.m. Cattle on the ranch subsisted mainly on grass and hay. Guinea corn stalks and leaves and rice chaff in limited amounts were provided during the dry season. Mineral blocks were also provided.

## COLLECTION OF BLOOD SAMPLES

Blood samples were obtained by venipuncture into plain vacutainer tubes[a] and allowed to clot. The samples were transported to the clinical pathology laboratory, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria under cold storage conditions. At the laboratory, the clots were removed, the tubes centrifuged[b] at 3500 rpm and the serum decanted into iron-free glass test tubes and frozen until analysed.

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[a] Jintan Terumo Co. Ltd; Tokyo, Japan.

[b] International Equipment Co. Needham, Mass., USA.

## CHEMICAL METHODS

Serum iron, unbound iron-binding capacity (UIBC) and total iron-binding capacity (TIBC) were determined by the method of O'Malley et al., (1970) using commercially prepared reagents[c] and percentage saturation of transferrin (SC) was calculated.

## RESULTS

Mean values, standard deviation and ranges of SI, UIBC, TIBC and SC in the cattle examined are presented in table 1. Individual values are presented in appendix 3. SI in calves from birth to 4 weeks was significantly lower ($P < .01$) than the SI in all other age groups. There was no significant difference in SI of calves 5 weeks to 1 year and 1 year to 3 years of age. Adult cattle had a significantly lower ($P < .01$) SI than that of cattle in the younger groups.

The serum UIBC of calves from birth to 4 weeks was significantly higher ($P < .01$) than all the other categories of cattle. The serum UIBC progressively decreased with advancing age.

Serum TIBC of calves from birth to 4 weeks was significantly higher ($P < .01$) than that of heifers, and adult cows. The TIBC decreased with advancing age beginning with the age group 5 weeks to 1 year.

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[c] Harleco Serum Iron Kits. Phil. Pa. USA.

Percentage saturation of transferrin was significantly lower ($P < .01$) in calves from birth to 4 weeks of age than in any other age group. It can be seen that SC values progressively increased with advancing age.

## DISCUSSION

Values for SI, UIBC, TIBC and SC recorded were in general agreement with observations in other breeds of cattle (Matrone et al., 1957; Bremner, 1966; and Gurtler and Schutzler, 1971). Calves from birth to 4 weeks had significantly lower ($P < .01$) SI than any other group. The low SI in this age group was probably related to the fact that they were fed only on milk. As the calves began to ingest vegetable feed, the SI increased to adult levels. The low SI in young calves resulted in high UIBC. The SI was stable in calves 5 weeks to 1 year and in those 1 to 3 years of age but decreased in older cattle. After 4 weeks, there was a gradual decrease in UIBC. The progressive decrease in TIBC beginning from the age group 5 weeks to 1 year reflected the decrease in both SI and UIBC as the cattle aged. Tartour (1973) also observed a progressive decrease in SI and TIBC in Zebu cattle with advancing age. The SC was lower in young calves and

progressively increased with age. It can be seen in table 1 that marked variations occurred in these parameters as cattle became advanced in age. It is interesting to note that, in spite of these variations, mean values were still within the generally accepted normal range for cattle.

## SUMMARY

The influence of age on serum iron and iron-binding capacity in Zebu cattle were investigated. Serum iron was lower in calves from birth to 4 weeks than in older cattle. UIBC and TIBC decreased while SC increased with advancing age.

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TARTOUR, G. (1973): The variation with age of the serum iron concentration and iron-binding capacity in Zebu cattle. Res. Vet. Sci. 15: 389-391.

Table 1: Means, standard deviations and ranges of SI, UIBC, TIBC and %C in Zebu cattle according to age group.

| Age Group | No. of Animals | SI ug/dl | UIBC ug/dl | TIBC ug/dl | % C |
|---|---|---|---|---|---|
| From birth to 4 weeks | 34 | 110.3 ± 38.8 (45 - 190) | 191.6 ± 55.1 (117.5-306) | 301.9 ± 65.7 (152.5-412) | 36.5 ±10.9 (19.6-56.3) |
| 5 weeks - 1 years | 37 | 141.1 ± 47.3 (68 - 275) | 187.8 ± 64.6 ( 80 - 320) | 328.9 ± 79.5 (172 - 520) | 42.9 ±12.4 (22.6-66.7) |
| 1 - 3 years | 42 | 141.2 ± 33.8 (72.5-206.5) | 147.9 ± 36.1 ( 80 - 230) | 289.1 ± 46.5 (217.5-357.5 | 48.8 ±12.2 ( 31 - 77.3) |
| Adults | 28 | 130.9 ± 30.5 (85 - 200) | 115.3 ± 45.5 ( 44 - 210) | 246.6 ± 45.4 (175 - 360) | 53.2 ±12.9 ( 28 - 82) |

# VII: CLINICO - PATHOLOGIC FINDINGS IN ZEBU CATTLE EXPERIMENTALLY INFECTED WITH T. VIVAX

## INTRODUCTION

Trypanosoma vivax (T. vivax) is the most important trypanosome afflicting livestock in Nigeria. The parasite produces a disease in cattle with anaemia as the principal pathologic feature. The pathology of trypanosomiasis has been recently reviewed (Fiennes, 1970; Losos and Ikede, 1972; Murray, 1974; Ikede, 1975). This chapter deals with the haematologic, histopathologic and serum iron and iron-binding capacity changes in cattle for a period of up to 2 months following experimental infection with two strains of T. vivax.

## MATERIALS AND METHODS

### Animals:

Three groups of apparently healthy Zebu cattle aged $1\frac{1}{2}$ to $4\frac{1}{2}$ years were utilized. All cattle originated from known tsetse-fly-free areas of Nigeria. Cows in groups 1 and 3 were observed for 3 weeks and those in group 2 for 2 weeks prior to infection. They were all treated with thiabendazole[a] and sprayed weekly with 0.05% Supona[b] during the experiment. They were fed a mixture of ground guinea

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[a] Thiabendazole. Merck Sharp and Dohme Ltd; Hoddesdon, England.

[b] Supona. 2-chloro-1-(2-4-dichlorophenyl) vinyldiethyl phosphate. Shell Company.

corn and linted cotton seed every morning before being taken to pasture for 6 to 8 hours. No mineral supplementation was provided. Water was provided ad libitum. Cows in group 2 were treated weekly before and during the experiment with Terramycin[c] at therapeutic levels in an attempt to minimize the effects of Anaplasma marginale presumed to be present at subclinical levels.

Experimental Procedure:

Group 1 consisted of 6 cows (Nos. 12, 13, 14, 15, 16, 17) which were infected with a mouse infective strain of T. vivax (Y58) isolated from a naturally infected N'Dama cow (Leeflang et al., 1975). The isolate was maintained in mice and cattle through 111 passages before being transferred to a donor cow. Blood from the donor cow was used to infect the 6 cows intravenously with approximately $3 \times 10^4$ trypanosomes in heparinized blood. Group 2 consisted of 6 cows (Nos. 27, 28, 29, 30, 31, 32). They were infected with another mouse infective strain of T. vivax (V953) isolated from a natural bovine infection (Leeflang et al., 1975). The strain was deep frozen in 5% DMSO and stored for a few months at -85°C before inoculation into a donor cow.

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[a] Terramycin. Pfizer Corp. Brussels, Belgium

Each of the 6 cows was intravenously inoculated with 10 ml of heparinized blood from the donor cow containing approximately 6500 trypanosomes per $mm^3$. Four cows in group 3 (Nos. 18, 19, 20, 21) were used as controls for both experiments.

The effects of trypanosomiasis were monitored by clinical signs, haematological and serum iron evaluation, rectal temperature and degree of parasitaemia. Trypanosome numbers were estimated using the method of Petana (1963) and reported as number per $mm^3$.

Sampling:

Blood samples were obtained from the jugular vein into plain vacutainer tubes[d], allowed to clot at room temperature and centrifuged[e] at 3,500 rpm for 15 minutes. Serum was decanted into iron-free tubes and frozen until analysed. Unclotted blood samples were collected in vacutainer tubes containing EDTA as anticoagulant. Cows in group 1 were sampled 2 or 3 times weekly and group 2 cows daily (except Sundays and holidays). Control cows were bled once a week. All blood samples were taken between 0700 and 0800 hours.

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[d] Jintan Terumo Co. Ltd., Tokyo, Japan.

[e] International Equipment Co., Needham, Mass. USA.

The experiment with group 1 cows was terminated at 47 days post inoculation while group 2 was terminated at 63 days post infection. All cows that had died during the experiments or were euthanized at the end of the experiments were necropsied. Specimens of liver, spleen, lymph nodes, kidney and bone marrow were fixed in 10% buffered formalin, embedded in paraffin, sectioned at 6u and stained with haematoxylin and eosin (H & E) for microscopic examination. Bone marrow smears were made at necropsy and stained with Giemsa's stain.

Haematology:

Haemoglobin (Hb) was estimated by the cyanmethaemoglobin method. The packed cell volume (PCV) was determined using a microhaematocrit centrifuge[f]. Erythrocytes (RBC) and leukocytes (WBC) were enumerated using the improved Neubauer haemocytometer. Thin blood films were stained with Giemsa's stain for morphologic evaluation of erythrocytes and leukocytes. Differential leukocyte counts were based on 100 cells. Reticulocyte counts of 2 cows in group 2 were monitored.

Chemical methods:

Serum iron (SI) unbound iron-binding capacity (UIBC)

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[f] Micro-capillary Centrifuge, Model M.D. International Equipment Co., Needham, Mass. USA.

and total iron-binding capacity (TIBC) were determined by the method of O'Malley et al., (1970). Percentage saturation of transferrin (SC) was calculated.

## RESULTS

Clinical signs and parasitaemia:

All infected cows developed trypanosomiasis. Soon after establishment of patent infection, the cows became lethargic and began to lose weight and condition. Dull hair coats and pale mucous membranes were observed following onset of anaemia. Geophagia was frequently observed in one cow (No. 16). Superficial lymph nodes were noticeably enlarged. Periodic increases in rectal temperature were observed and coincided with periods of high parasitaemia. All cows had good appetite throughout the experimental period.

Three cows in group 1 (Nos. 13, 16 and 17) developed the acute form of trypanosomiasis while the remaining three (Nos. 12, 14 and 15) developed the chronic form of the disease. The degree of parasitaemia is presented in Fig. 1. Peak parasitaemia occured 5 days post inoculation and remained high until 3 weeks later when few trypanosomes were detected in peripheral blood. Thereafter, cyclic increases and decreases in trypanosome counts were observed.

One of the cows which developed acute trypanosomiasis (No. 16) died 22 days post infection. On the day prior to death, haemoglobinuria was observed and the rectal temperature was subnormal. Babesia bigemina and T. vivax were detected on thin blood smear examination. The other 2 cows with the acute form of trypanosomiasis deteriorated in condition until termination of the experiment. Babesia bigemina and Anaplasma marginale were detected in their blood 35 days post inoculation. They were immediately treated with therapeutic doses of Acaprine[g] and terramycin. The 3 cows with chronic form of trypanosomiasis did not show concurrent infections and their condition gradually improved.

All infected cows in group 2 developed the chronic form of trypanosomiasis. Parasitaemia is presented in Fig. 2. Numbers of trypanosomes in circulation increased rapidly following initial parasitaemia. Peak parasitaemia occurred 6 days post inoculation followed by a steady decrease. Except on two occasions, trypanosomes were detected in the peripheral blood throughout the experiment. A few Babesia bigemina were detected in the blood of 2 cows 7 days post inoculation. They were

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[g] Acaprine. Bayer, Leverkusen, Germany.

immediately treated with acaprine. Anaplasma marginale were detected in the blood of 2 other cows 29 and 54 days post inoculation in spite of weekly terramycin treatment. Both cows were treated with an additional dose of terramycin. Intercurrent infections were not observed in the other infected or control cows.

Haematological findings:

Mean haematologic values of infected cows in group 1 are presented in table 1. Values for individual cows are presented in appendix 4. Mean haematologic values of control cows are presented in table 2 and individual values in appendix 5.

The course of trypanosomiasis in individual cows and the effect of concurrent infections was reflected in changes in erythrocyte values. Cows with acute trypanosomiasis had a marked decrease in RBC, Hb and PCV 5 days post inoculation. The decrease continued until 3 weeks post infection when they gradually increased. One of the cows died of acute babesiosis 22 days post inoculation. Cows which developed the chronic form of the disease had a more gradual decrease in RBC, Hb and PCV. These values were lowest between 10 and 21 days post inoculation, followed by a steady increase. The values, however, did

not return to preinfection levels when the experiment was terminated. The development of anaemia was accompanied by peripheral blood morphologic changes. These included anisocytosis, polychromatophilia and punctate basophilia and were observed as early as 10 days post inoculation.

Percentage changes in total leukocytes, neutrophils and lymphocytes in these cows are presented in Fig. 3. Total leukocytes were below preinfection values for 3 weeks post infection followed by a moderate increase above preinfection values. A marked lymphopenia occurred in association with initial pyrexia. Lymphocyte counts remained below preinfection levels until 3 weeks post infection when a gradual increase was observed. Although there was no consistent pattern of changes in neutrophils, most instances of neutrophilia coincided with fever.

Mean haematologic values of cows in group 2 are presented in table 3. Haematologic findings in individual cows are presented in appendix 4.

There was a gradual decrease in Hb, PCV and RBC in infected cows beginning 5 days post inoculation. The lowest PCV was recorded 7 weeks post infection followed by a gradual increase. The Hb, PCV and RBC values did not attain preinfection values except in one cow (No. 29)

The erythrocyte morphologic changes most commonly observed included anisocytosis, polychromatophilia and basophilic stippling. A few metarubricytes were observed in one cow at the peak of anaemia. The degree of morphologic changes varied from one cow to another. There was a gradual increase in reticulocyte count of 2 cows from 0% at the time of initial infection to 4% at the peak of anaemia.

All cows developed a leukopenia early in disease followed by an increase in neutrophils, lymphocytes and total leukocytes above preinfection levels. The percentage changes in total leukocytes, neutrophils and lymphocytes are presented in Fig. 4. Haemograms in the control cows were within the normal range for cattle in this area (Fig. 5).

Serum iron and iron-binding capacity:

The mean SI, UIBC, TIBC and SC in group 1 infected cows and controls are presented in tables 4 and 5 respectively. Individual cow data are presented in appendix 4. Percentage changes in SI, UIBC, TIBC, SC and PCV in infected cows are presented in Fig. 6 and for controls in Fig. 7.

There was a decrease in SI, UIBC, TIBC and SC early in disease with the lowest values coinciding with initial

peak pyrexia and parasitaemia. By the 10th day post infection, the SC was at preinfection level. Moderate increases in SC were observed at 4 weeks and again at 6 weeks post infection. The SI was below preinfection values until 3 weeks post infection when normal values were attained. A moderate increase in SI occurred late in disease. The TIBC and UIBC were low throughout the experimental period.

Mean SI, UIBC, TIBC and SC of group 2 cows are presented in table 6. Individual values are presented in appendix 4. Percentage changes in SI, UIBC, TIBC, SC and PCV are presented in Fig. 8. While TIBC and UIBC decreased early in disease and remained low throughout the infection; the SI and SC were higher than pre-infection levels. It is evident that UIBC and SC were the parameters most affected.

Bone marrow cytology:

The cytologic findings in bone marrow of groups 1 and 2 cows were similar. Red marrow was present in the ribs, sternabrae and proximal aspects of long bones. The rest of the marrow space in long bones was filled by fatty gelatinous material. Microscopic examination of marrow smears revealed active erythropoiesis as evidenced by the

presence of many prorubricytes, basophilic and polychromatic rubricytes (Fig. 9). Developing and mature eosinophilic granulocytes were present in varying numbers (Fig. 10). There were relatively few developing neutrophilic granulocytes. Myeloid erythroid ratio was estimated as 1:1. It was not possible to do an accurate count as there were many degenerate cells. Lymphoid cells and plasma cells were present in varying numbers (Fig. 11). A few mononuclear cells with the morphologic features of plasma cells but containing numerous vacuoles in the distended cytoplasm were present (Fig. 12). These cells were morphologically indistinguished from those classically referred to as Russell bodies. Erythrophagocytosis was observed in bone marrow smears of some cows. Megakaryocytes were abundant and degenerating trypanosomes were present in some smears.

Histologic observations:

No inflammatory or necrotic changes were observed in any organs. Germinal centres were present in all spleen sections. The spleen was hypercellular and congested. The red pulp was diffusely infiltrated by lymphocytes and plasma cells. Reticulo-endothelial cells and macrophages were prominent in the sinuses and contained haemosiderin (Fig. 13). The cytoplasm of many macrophages was distended

and vacuolated. No distinct cellular structures were discerned but the morphologic features of the vacuoles suggested erythrophagia. Clear instances of erythrophagia were occasionally observed. There was no evidence of haematopoiesis in the spleen.

The lymph nodes were hyperplastic. Some had many normal germinal centres while in others, the germinal centres were disorganized and contained many large immature and medium sized lymphocytes and plasma cells. Plasma cells and haemosiderin - laden macrophages were abundant in the medullary areas.

Degenerative changes were observed in many livers. The hepatocytes were swollen and had vacuolated granular cytoplasm. Hepatic cords were disorganized and many sinusoidal spaces were obliterated by the swollen hepatocytes. Kupffer cells were prominent and many were engorged with haemosiderin. Mononuclear cell infiltration in areas of the hepatic triad were occasionally observed. There was no evidence of haematopoiesis.

The most characteristic alteration in the kidney was mononuclear cell accumulation in the vicinity of the glomeruli and around some blood vessels. These cells were mostly monocytes and lymphocytes, with lymphocytes predominating. Vacuolation and sloughing of some tubular

epithelial cells was observed. Epithelial casts were present in the lumina of some cortical and medullary tubes.

Active marrow was present in the peripheral aspects of long bones while the central areas contained adipose tissue. Many clusters of erythrocytes and their precursors were separated by scanty adipose tissue within active marrow. Granulocytopoiesis was moderate. Some marrow sections contained numerous eosinophils. Lymphocytes and plasma cells were present in varying numbers. Megakaryocytes were abundant in all sections.

## DISCUSSION

The mouse infective strains used in these experiments did not show any apparent changes in their pathogenecity for natural hosts, therefore, they were considered as valid representatives of the species (Leeflang et al., 1975). All cows developed trypanosomiasis following a single inoculation with either strain. The chronic form of infection predominated.

The 3 cows in group 1 which developed acute trypanosomiasis also suffered from concurrent infection with Babesia bigemina or Anaplasma marginale. These infections were also present in some group 2 cows but

their effect was controlled by regular terramycin treatment. Since intercurrent infections were not observed in control cows, it was assumed that the clinical appearance of these intercurrent infections was triggered by trypanosomiasis.

The results indicated that Zebu cattle were able to withstand a single infection of trypanosomes. In the field, continous exposure to tsetse fly occurs. This, together with dormant tick-borne infections is probably responsible for the fatal course of T. vivax infection in adult Zebu cattle under natural conditions.

Results of these studies indicated that T. vivax infection in Zebu cattle was characterized by high parasitaemia. The highest parasitaemia occurred 3-5 days post infection and remained high for 3 to 4 weeks. The parasitaemia declined as the disease progressed into chronicity. Similar pattern of parasitaemia has been reported in cattle (Fiennes, 1954), sheep and goats (Edwards et al., 1956) with T. vivax infection. Isoun and Anosa (1975) reported peak parasitaemia during the terminal stages of the disease in goats and sheep; a feature not observed in these trials.

Anaemia was the most significant pathologic feature in cattle with T. vivax infection. The onset of anaemia coincided with initial parasitaemia and pyrexia. The

anaemia was progressive for 4 to 6 weeks followed by an attempt at recovery in animals that survived. The pattern of development of anaemia suggested that the disease produced by these trypanosomes in cattle is essentially chronic in nature. The anaemia that developed was normocytic normochromic as judged from mean corpuscular volume and mean corpuscular haemoglobin concentration estimations.

The principal erythrocytic morphologic features in infected cows were anisocytosis, polychromatophilia, basophilic stippling and occasional nucleated erythrocytes. These findings are indicative of regenerative anaemias that may result from either erythrocyte loss or lysis (Schalm, 1972). Since no evidence was found for internal or external blood loss in our infected cows, it was presumed the anaemia arose from erythrocyte ~~lysis~~ destruction. Erythrophagocytosis in the bone marrow and increased haemosiderin deposition in bone marrow, spleen and lymph nodes indicated erythrocyte destruction by phagocytosis and that the destruction occurred principally in the macrophages of the reticuloendothelial organs. Fiennes (1954) observed that one of the principal causes of anaemia in Zebu cattle with T. vivax infection was removal of erythrocytes in the circulation and their sub-

sequent destruction in the reticuloendothelial organs. MacKenzie and Cruickshank (1973) reported intense erythrophagocytosis in the reticuloendothelial system of sheep infected with T. congolense and suggested that it may have been the major factor in the development of anaemia. Similar observations have been made in rats and mice with T. brucei infection (Jennings et al., 1974).

A severe intravascular haemolysis has been observed in cattle with T. vivax infection during the acute and relapsing stages (Fiennes, 1954). The intravascular haemolysis was thought to have resulted from the presence of haemolysin in the plasma. The nature of this haemolysin has not been established and requires further investigation.

Fiennes (1954) and Clarkson, (1968) suggested that hydraemia was a contributing factor to the development of anaemia in ruminants infected with T. vivax. Similar observations were made in cattle with T. congolense infection (Naylor, 1971). Holmes and Mamo (1975) observed that as the anaemia developed in T. congolense infected calves, there was an absolute fall in the circulating red cell mass and an over-compensatory increase in plasma volume. However, they suggested that the haemodilution effect was of secondary importance in bringing about the

anaemia. Further studies are required to clarify the effect of hydraemia and other factors in the development of anaemia in trypanosomiasis.

The increased erythropoiesis observed in the bone marrow reflects the regenerative nature of the anaemia. The regenerative process did not, however, keep pace with erythrocyte destruction hence the progressive developing anaemia. The role of dyshaematopoiesis in the development of anaemia needs further investigation.

Isoun and Anosa (1975) observed that T. vivax infection in cattle, sheep and goats was characterized by a depletion of mature lymphocytes from the spleen and lymph nodes. In contrast, benign lymphoid hyperplasia of the spleen and lymph nodes characterized by the presence of various sized lymphocytes, some in mitosis, and plasma cells were observed in our infected cows. Lymphoid hyperplasia of the spleen and lymph nodes has previously been reported in ruminants (Losos et al., 1973; MacKenzie and Cruickshank, 1973) and laboratory animals (Jennings et al., 1974) with trypanosomiasis.

In chronically infected cattle, Fiennes (1954) observed that the anaemia was microcytic and the spleen atrophied which suggested the possibility of iron deficiency or bone marrow failure. Iron-deficiency

anaemias are generally characterized by very low serum iron, high TIBC and low percentage saturation of transferrin (Moore et al., 1937; Hillman, 1970). SI in our infected cows was generally below pre-infection levels, however, it was never low enough to warrant the designation of iron-deficiency. Transient decreases in SI were observed early in disease in association with initial high parasitaemia and pyrexia. This may have resulted from a rapid removal of serum iron by the reticuloendothelial organs to meet the demand for erythropoiesis or from the increased plasma volume that is said to characterize this phase of the disease.

Tartour and Idris (1973) observed a hypoferremia in 2 calves (after 20 weeks of infection) that lasted for several weeks. Hypoferremia during this stage of the disease would suggest depletion or failure of release of storage iron. Protracted hypoferremia was not observed in these experiments. Rather, a moderate increase in SI above preinfection levels was recorded in one group of cattle. Preliminary findings on serum copper levels in these T. vivax infected cattle revealed no hypocupremia at any stage of the disease (Saror, 1975). While it may be conceded that iron deficiency could develop in chronically infected cattle for reasons outlined above,

the development of anaemia in the first 9 weeks of infection was not associated with either iron or copper deficiency. The occasional increases in serum iron observed probably resulted from a release of iron into the plasma as a result of erythrocyte destruction.

The UIBC and TIBC were reduced throughout the infection in both groups of cows. The SC fluctuated randomly but was usually high late in disease and in cows in anaemic crisis. Tartour and Idris (1973) observed that full saturation of transferrin appeared to be a constant feature of collapse before death in acute and chronic T. congolense infection in Zebu cattle.

## SUMMARY

Two groups of apparently healthy Zebu cattle were inoculated with 2 mouse infective strains of T. vivax. All inoculated cows developed trypanosomiasis. The course of disease was predominantly chronic and anaemia was the most significant pathologic feature. Three cows which developed acute trypanosomiasis also suffered from concurrent infection with Babesia bigemina or Anaplasma marginale. The onset of anaemia coincided with initial parasitaemia which was massive and sustained. Peripheral

blood morphologic changes consisted of anisocytosis, polychromatophilia and basophilic stippling. There was active erythropoiesis in bone marrow. Erythrophagocytosis and marked haemosiderosis were observed in the bone marrow, spleen, lymph nodes and livers. Serum iron was predominantly below preinfection levels. Hypoferremia was not observed. It was concluded that the anaemia resulted from accelerated erythrocyte destruction in the reticuloendothelial system. Iron deficiency was not a factor in development of anaemia.

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Table 1 : Means and standard deviations of PCV, Hb, RBC and rectal temperature in six cattle experimentally infected with T. vivax strain Y58.

| Days of Experiment | PCV % | Hb gm/dl | RBC x $10^6/mm^3$ | Temp. $^oC$ |
|---|---|---|---|---|
| -2 | 31.6 ± 2.4 | 10.7 ± 0.9 | 6.67 ± 0.56 | 38.40 ± 0.32 |
| 0 | 30.8 ± 2.9 | 10.5 ± 1.3 | 7.05 ± 1.53 | 38.68 ± 0.10 |
| 2 | 30.4 ± 2.3 | 9.8 ± 0.8 | 6.70 ± 0.54 | 38.78 ± 0.26 |
| 4 | 28.6 ± 5.5 | 9.5 ± 1.7 | 6.90 ± 0.95 | 39.40 ± 0.54 |
| 5 | 23.8 ± 2.8 | 8.2 ± 0.9 | 5.19 ± 0.99 | 39.75 ± 0.40 |
| 6 | 22.8 ± 3.4 | 7.5 ± 1.3 | 4.78 ± 1.11 | 40.10 ± 0.62 |
| 7 | 21.4 ± 3.1 | 7.2 ± 0.9 | 4.35 ± 0.80 | 39.58 ± 0.67 |
| 8 | 21.0 ± 2.5 | 7.0 ± 0.8 | 4.76 ± 0.63 | 39.70 ± 0.65 |
| 9 | 20.6 ± 3.4 | 6.8 ± 1.3 | 4.90 ± 1.11 | 39.10 ± 0.66 |
| 10 | 21.0 ± 2.9 | 6.8 ± 1.1 | 4.66 ± 1.03 | 39.10 ± 0.50 |
| 11 | 21.2 ± 2.9 | 6.9 ± 1.2 | 4.90 ± 1.22 | 39.07 ± 0.29 |
| 12 | 23.4 ± 3.0 | 7.2 ± 1.1 | 4.54 ± 0.96 | 39.35 ± 0.67 |
| 14 | 22.6 ± 4.0 | 7.7 ± 1.4 | 4.96 ± 1.01 | 39.43 ± 0.53 |
| 16 | 23.4 ± 3.4 | 7.9 ± 1.3 | 4.59 ± 1.01 | 39.60 ± 0.53 |
| 19 | 22.0 ± 4.1 | 7.5 ± 1.4 | 4.99 ± 0.99 | 39.80 ± 0.55 |
| 21 | 19.8 ± 4.7 | 6.4 ± 1.8 | 4.44 ± 1.20 | 39.60 ± 1.15 |
| 23 | 22.6 ± 4.3 | 7.2 ± 4.3 | 4.81 ± 1.48 | 39.60 ± 0.42 |
| 26 | 21.8 ± 4.1 | 7.6 ± 1.7 | 4.68 ± 1.25 | 39.52 ± 0.29 |
| 28 | 22.0 ± 3.4 | 7.7 ± 1.1 | 4.46 ± 0.87 | 39.96 ± 0.57 |
| 30 | 22.0 ± 3.7 | 7.3 ± 1.3 | 4.52 ± 0.76 | 39.24 ± 0.09 |
| 33 | 21.2 ± 3.0 | 7.0 ± 0.9 | 4.85 ± 1.81 | 40.58 ± 0.58 |
| 37 | 23.4 ± 4.7 | 7.8 ± 1.7 | 4.88 ± 1.42 | 39.64 ± 0.54 |
| 40 | 22.8 ± 4.3 | 7.4 ± 1.5 | 5.17 ± 1.52 | 39.40 ± 0.39 |
| 47 | 23.2 ± 5.9 | 7.7 ± 2.1 | 4.65 ± 1.49 | 39.22 ± 0.28 |
| 54 | 23.4 ± 7.33 | 7.74 ± 3.2 | 4.73 ± 2.09 | 38.78 ± 0.84 |

Table 2 : Mean and standard deviations of haematologic parameters of 4 control cows.

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | W B C | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -2 | 34.3 | 11.3 | 8.56 | 13,450 | 66 | 30 | 1.2 | 1.8 |
| | ± 5.7 | ± 1.9 | ± 1.58 | ±3,626 | ± 7 | ± 7 | ±1.5 | ± 1.5 |
| 0 | 33.8 | 11.3 | 7.65 | 11,512 | 68 | 27 | 3.8 | 0.3 |
| | ± 5.6 | ± 1.7 | ± 1.00 | 4,804 | ±10 | ± 9 | ±3.8 | ± 0.5 |
| 7 | 32.8 | 10.9 | 7.92 | 10,862 | 69 | 26 | 4.8 | 0.0 |
| | ± 3.9 | ± 1.4 | ± 1.60 | 5,819 | ± 6 | ± 8 | ±3.5 | 0.0 |
| 14 | 31.5 | 10.5 | 6.67 | 13,475 | 73 | 22 | 1.0 | 4.0 |
| | ± 3.4 | ± 1.2 | ± 1.41 | ±4,557 | ± 8 | ± 8 | ±1.4 | ± 2.5 |
| 21 | 32.0 | 10.8 | 7.69 | 13,137 | 72 | 24 | 2.3 | 1.8 |
| | ± 4.4 | ± 1.4 | ± 2.00 | ±5,889 | ±11 | ±10 | ±1.7 | ± 0.5 |
| 28 | 30.3 | 10.3 | 6.03 | 12,287 | 72 | 22 | 3.0 | 2.3 |
| | ± 2.9 | ± 1.1 | ± 0.73 | ±4,482 | ±10 | ± 7 | ±3.3 | ± 1.9 |
| 35 | 32.0 | 10.8 | 7.11 | 11,800 | 72 | 24 | 1.8 | 2.3 |
| | ± 2.2 | ± 0.9 | ± 1.38 | ±4,721 | ± 7 | ± 6 | ±1.7 | ± 2.1 |
| 42 | 29.3 | 10.0 | 6.75 | 11,225 | 73 | 23 | 2.0 | 1.3 |
| | ± 1.9 | ± 0.8 | ± 1.56 | ±7,684 | ±10 | ± 8 | ±2.2 | ± 0.5 |
| 49 | 30 | 10.3 | 6.09 | 13,412 | 66 | 27 | 4.3 | 2.5 |
| | ± 0.8 | ± 0.6 | ± 0.68 | ±6,860 | ± 8 | ± 6 | ±4.6 | ± 1.0 |
| 56 | 29.5 | 9.8 | 5.96 | 13,000 | 69 | 25 | 3.8 | 1.5 |
| | ± 1.3 | ± 0.6 | ± 0.73 | ±5,478 | ±10 | ± 7 | ±4.8 | ± 1.9 |
| 63 | 29.8 | 10.1 | 5.74 | 13,425 | 71 | 24 | 2.0 | 2.3 |
| | ± 0.9 | ± 0.4 | ± 0.60 | ±4,794 | ± 9 | ± 8 | ±2.8 | ± 2.1 |

Table 3 : Means and standard deviations of PCV, Hb and WBC in six cows experimentally infected with T. vivax.

| Days of Expt. | PCV % | Hb gm % | W B C |
|---|---|---|---|
| -3 | 31.4 ± 2.3 | 10.1 ± 0.8 | 7950 ± 2196 |
| -1 | 30.2 ± 1.6 | 9.5 ± 0.7 | 7008 ± 2230 |
| 0 | 28.7 ± 1.6 | 9.0 ± 0.6 | 6217 ± 1726 |
| 3 | 31.2 ± 1.6 | 10.0 ± 0.5 | 5883 ± 1928 |
| 5 | 29.2 ± 2.4 | 9.1 ± 1.2 | 3858 ± 1165 |
| 9 | 26.6 ± 2.1 | 8.8 ± 1.4 | 7420 ± 1308 |
| 11 | 23.3 ± 7.7 | 8.5 ± 1.3 | - - |
| 13 | 24.4 ± 3.0 | 7.8 ± 0.8 | 8760 ± 1555 |
| 15 | 25.8 ± 3.1 | 8.0 ± 0.9 | - - |
| 17 | 23.3 ± 1.9 | 7.0 ± 0.7 | 7962 ± 657 |
| 19 | 22.8 ± 3.9 | 6.9 ± 1.3 | 7030 ± 1435 |
| 21 | 23.0 ± 4.0 | 7.1 ± 1.9 | 10062 ± 4037 |
| 23 | 22.0 ± 1.4 | 7.0 ± 0.1 | 12275 ± 621 |
| 25 | 24.0 ± 3.7 | 7.3 ± 1.0 | 10108 ± 1401 |
| 27 | 22.8 ± 2.8 | 6.8 ± 1.2 | 7900 ± 1638 |
| 29 | 22.2 ± 3.9 | 6.8 ± 1.3 | - - |
| 31 | 23.0 ± 3.6 | 6.6 ± 1.4 | 13416 ± 5168 |
| 33 | 23.4 ± 3.3 | 7.3 ± 1.5 | - - |
| 35 | 21.8 ± 4.6 | 6.5 ± 1.3 | - - |
| 39 | 21.3 ± 4.7 | 6.7 ± 1.9 | 12408 ± 4981 |
| 42 | 20.6 ± 3.0 | 6.6 ± 1.3 | - - |
| 46 | 22.7 ± 3.4 | 6.7 ± 1.1 | 15116 ± 5359 |
| 49 | 17.8 ± 9.7 | 6.8 ± 1.2 | - - |
| 54 | 22.3 ± 4.7 | 7.4 ± 1.5 | 11408 ± 4842 |
| 56 | 22.8 ± 4.2 | 7.6 ± 1.6 | 9733 ± 3766 |
| 61 | 25.7 ± 3.7 | 8.2 ± 1.4 | 9608 ± 2563 |

Table 4: Mean and standard deviations of SI, UIBC, TIBC of SC in 6 cattle experimentally infected with T. vivax. strain Y58.

| Days of Experiment | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 133.0 ± 18.6 | 196.0 ± 37.3 | 329.0 ± 54.9 | 40.6 ± 2.1 |
| 0 | 135.8 ± 17.2 | 194.4 ± 39.1 | 332.6 ± 39.8 | 41.3 ± 6.8 |
| 2 | 101.0 ± 13.4 | 208.0 ± 45.4 | 309.2 ± 50.8 | 33.1 ± 4.4 |
| 4 | 76.0 ± 21.9 | 191.6 ± 53.4 | 267.6 ± 45.8 | 29.3 ±10.4 |
| 5 | 59.0 ± 13.4 | 197.4 ± 29.6 | 256.4 ± 17.5 | 23.1 ± 6.3 |
| 6 | 72.4 ± 13.6 | 192.6 ± 48.1 | 265.0 ± 44.0 | 29.2 ± 7.9 |
| 7 | 102.4 ± 9.6 | 146.0 ± 34.9 | 248.4 ± 35.3 | 41.9 ± 7.1 |
| 8 | 81.0 ± 26.8 | 153.4 ± 66.2 | 234.4 ± 56.6 | 36.7 ±16.7 |
| 9 | 89.8 ± 42.9 | 211.6 ± 94.1 | 301.4 ± 74.6 | 31.5 ±17.1 |
| 10 | 110.2 ± 34.2 | 156.0 ± 45.1 | 260.2 ± 40.2 | 41.9 ±12.6 |
| 11 | 109.2 ± 11.2 | 159.2 ± 33.0 | 268.4 ± 34.9 | 41.1 ± 5.9 |
| 12 | 115.6 ± 23.0 | 182.6 ± 38.3 | 298.2 ± 33.9 | 39.1 ± 7.5 |
| 14 | 104.4 ± 19.2 | 162.0 ± 35.6 | 266.4 ± 34.9 | 39.5 ± 7.4 |
| 16 | 123.4 ± 20.9 | 164.0 ± 31.9 | 287.4 ± 29.1 | 43.1 ± 7.7 |
| 19 | 125.8 ± 25.4 | 185.4 ± 78.7 | 311.2 ± 70.9 | 41.9 ±13.2 |
| 21 | 110.6 ± 16.7 | 161.0 ± 75.4 | 271.6 ± 62.8 | 43.3 ±16.0 |
| 23 | 141.4 ± 60.8 | 178.6 ± 99.6 | 320.0 ± 65.7 | 44.9 ±21.4 |
| 26 | 145.6 ± 39.6 | 137.4 ± 26.8 | 283.0 ± 31.4 | 51.1 ± 9.9 |
| 28 | 108.0 ± 34.1 | 198.4 ±106.2 | 306.4 ± 76.2 | 38.4 ±17.1 |
| 30 | 125.8 ± 33.5 | 170.4 ± 45.8 | 297.0 ± 45.2 | 42.8 ±11.3 |
| 33 | 115.2 ± 42.0 | 197.8 ± 62.9 | 313.0 ± 53.8 | 37.4 ±15.3 |
| 37 | 126.0 ± 29.1 | 175.0 ± 41.4 | 301.0 ± 63.8 | 42.1 ± 5.4 |
| 40 | 147.8 ± 49.4 | 136.0 ± 35.3 | 282.8 ± 82.4 | 51.7 ± 4.0 |
| 47 | 159.0 ± 44.5 | 149.6 ± 54.6 | 308.6 ± 58.2 | 51.9 ±14.0 |

Table 5 : Mean and standard deviations of SI, UIBC, TIBC and SC in 4 control cows.

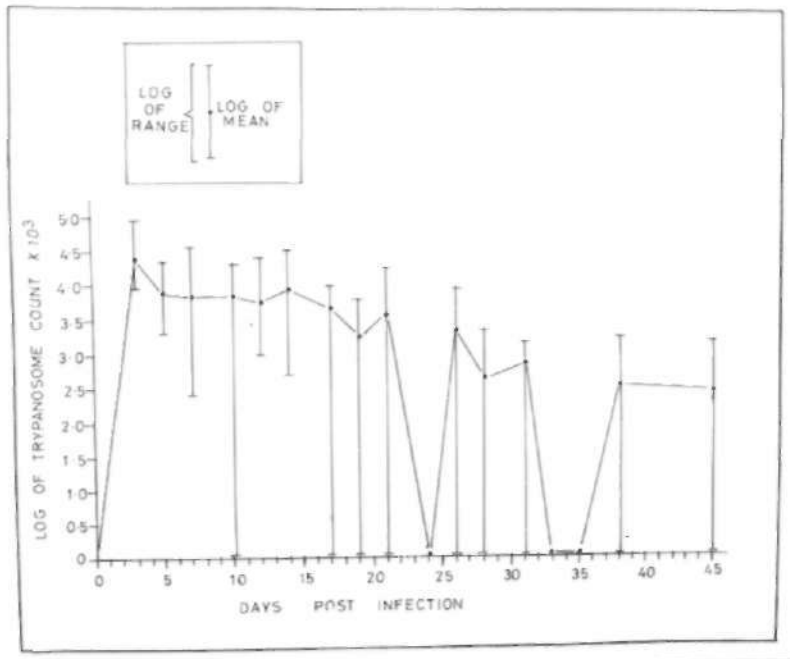
| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 127 ± 5.7 | 212 ± 17.1 | 339 ± 20.5 | 37 ± 1.6 |
| 0 | 133 ± 10.1 | 189 ± 22.5 | 322 ± 32.4 | 41 ± 1.3 |
| 7 | 133 ± 11.2 | 205 ± 40.4 | 338 ± 31.8 | 39.± 6.9 |
| 14 | 137 ± 9.4 | 196 ± 34.2 | 333 ± 40.6 | 41 ± 3.7 |
| 21 | 124 ± 10.9 | 186 ± 34.0 | 310 ± 37.5 | 40 ± 4.7 |
| 28 | 121 ± 19.8 | 200 ± 21.6 | 323 ± 18.9 | 37 ± 5.2 |
| 35 | 134 ± 12.4 | 210 ± 38.3 | 344 ± 40.8 | 39 ± 4.6 |
| 42 | 132 ± 11.2 | 203 ± 43.8 | 335 ± 53.3 | 39 ± 4.3 |
| 49 | 120 ± 5.7 | 187 ± 15.0 | 307 ± 18.2 | 39 ± 1.8 |
| 56 | 120 ± 18.4 | 210 ± 21.6 | 330 ± 30.7 | 36 ± 4.0 |
| 63 | 119 ± 2.1 | 194 ± 42.1 | 314 ± 41.1 | 38 ± 5.8 |

Table 6 : Means and standard deviations of SI, UIBC, TIBC and SC in 6 cows experimentally infected with T. vivax-strain V953.

| Days of Expt. | Plasma Iron ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 105.8 ± 24.6 | 134.0 ± 36.9 | 239.8 ± 40.1 | 44.5 ± 9.4 |
| 3 | 101.9 ± 18.7 | 141.1 ± 47.2 | 243.0 ± 47.2 | 42.8 ± 9.4 |
| 7 | 109.0 ± 35.4 | 59.8 ± 40.9 | 168.8 ± 30.1 | 66.0 ± 22.1 |
| 11 | 90.8 ± 25.3 | 104.8 ± 24.1 | 195.7 ± 34.7 | 46.3 ± 8.8 |
| 13 | 115.5 ± 20.4 | 77.0 ± 36.1 | 192.5 ± 34.2 | 61.4 ± 14.9 |
| 16 | 101.9 ± 26.0 | 122.1 ± 27.9 | 224.0 ± 30.1 | 45.5 ± 10.6 |
| 20 | 113.2 ± 19.3 | 78.9 ± 20.2 | 192.1 ± 31.8 | 59.3 ± 6.3 |
| 25 | 102.9 ± 28.6 | 76.6 ± 31.7 | 179.5 ± 28.1 | 58.1 ± 16.9 |
| 29 | 112.5 ± 23.1 | 93.2 ± 30.2 | 205.7 ± 9.7 | 55.1 ± 12.9 |
| 34 | 120.4 ± 22.6 | 76.0 ± 25.2 | 196.4 ± 20.8 | 61.6 ± 12.1 |
| 37 | 117.5 ± 27.1 | 102.5 ± 44.8 | 220.0 ± 35.2 | 55.1 ± 17.2 |
| 42 | 132.2 ± 19.8 | 100.4 ± 26.9 | 232.1 ± 17.1 | 57.4 ± 11.3 |
| 46 | 113.5 ± 23.1 | 80.8 ± 30.9 | 194.3 ± 19.4 | 58.9 ± 13.3 |
| 49 | 120.4 ± 25.8 | 84.8 ± 21.3 | 205.3 ± 8.8 | 58.5 ± 11.1 |
| 53 | 102.5 ± 31.2 | 119.8 ± 35.9 | 222.3 ± 28.0 | 46.4 ± 12.9 |
| 61 | 122.1 ± 18.8 | 87.6 ± 20.1 | 209.7 ± 26.3 | 58.4 ± 7.8 |
| 63 | 112.8 ± 14.1 | 74.4 ± 29.1 | 187.2 ± 21.2 | 61.2 ± 12.7 |

Fig. 1: Log of the mean and range of trypanosome counts in cows infected with Trypanosoma vivax strain Y58.

Fig. 2: Log of the mean and range of trypanosome counts in cows infected with Trypanosoma vivax strain V953.


LOG OF RANGE
LOG OF MEAN
LOG OF TRYPANOSOME COUNT X 10³
0
0·5
1·0
1·5
2·0
2·5
3·0
3·5
4·0
4·5
5·0
0
5
10
15
20
25
30
35
40
45
DAYS POST INFECTION

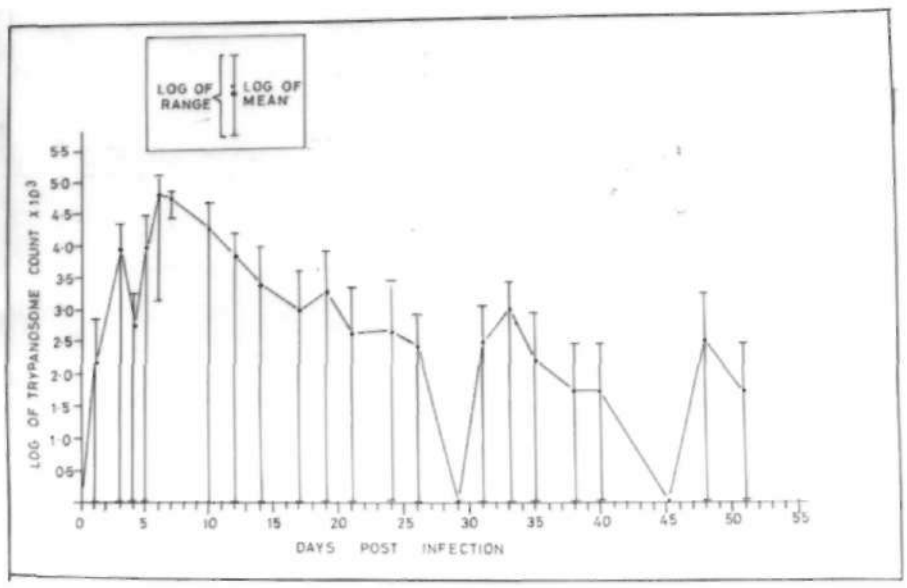
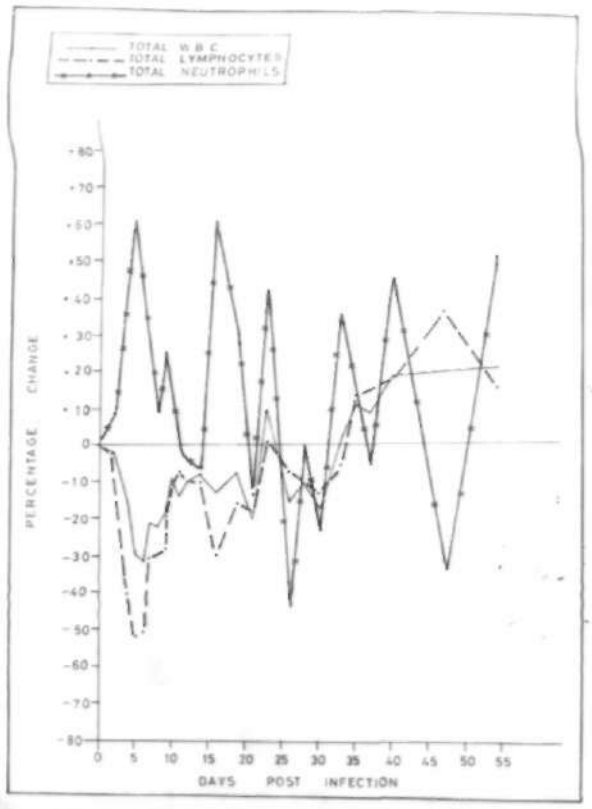

LOG OF RANGE
LOG OF MEAN
LOG OF TRYPANOSOME COUNT X 10³
0·5
1·0
1·5
2·0
2·5
3·0
3·5
4·0
4·5
5·0
5·5
0
5
10
15
20
25
30
35
40
45
50
55
DAYS POST INFECTION

Fig. 3: Per cent changes from mean preinfection values of total leukocytes, lymphocytes and neutrophils in cows infected with Trypanosoma vivax strain Y58.

Fig. 4: Per cent changes from mean preinfection values of total leukocytes, lymphocytes and neutrophils in cows infected with Trypanosoma vivax strain V953.


TOTAL W.B.C.
TOTAL LYMPHOCYTES
TOTAL NEUTROPHILS
PERCENTAGE CHANGE
+80
+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
0 5 10 15 20 25 30 35 40 45 50 55
DAYS POST INFECTION

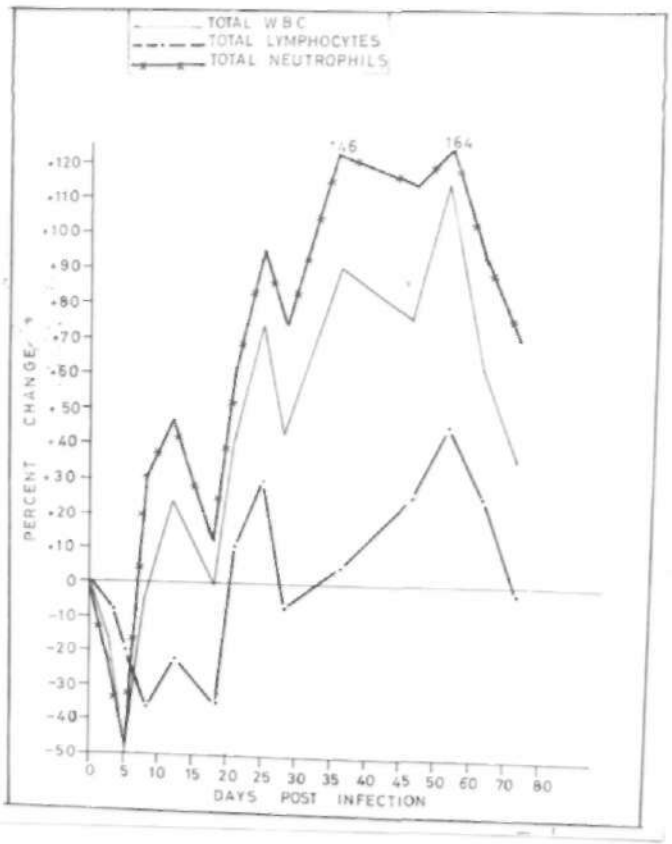
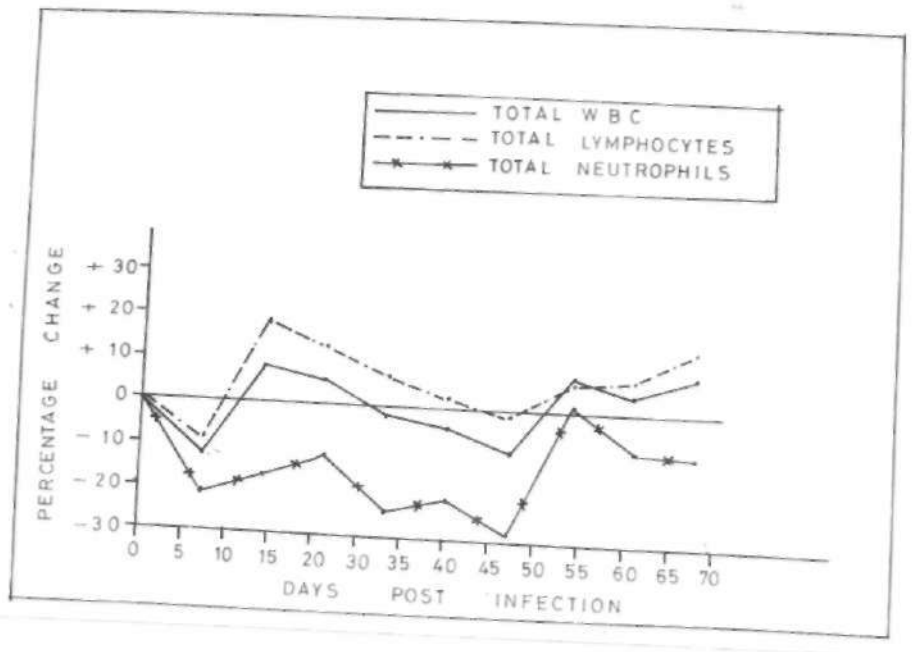

TOTAL W.B.C
TOTAL LYMPHOCYTES
TOTAL NEUTROPHILS
46
164
PERCENT CHANGE
+120
+110
+100
+90
+80
+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
0 5 10 15 20 25 30 35 40 45 50 60 70 80
DAYS POST INFECTION

Fig. 5: Per cent changes from mean preexperimental values of total leukocytes (WBC) lymphocytes and neutrophils of uninoculated control cows.

Fig. 6: Per cent changes from mean preinfection values of packed cell volume (PCV), serum iron (SI), unbound iron-binding capacity (UIBC), total iron-binding capacity (TIBC) and per cent saturation of transferrin (SC) in cows infected with Trypanosoma vivax strain Y58.


TOTAL W B C
TOTAL LYMPHOCYTES
TOTAL NEUTROPHILS
PERCENTAGE CHANGE
+ 30
+ 20
+ 10
0
− 10
− 20
−30
0 5 10 15 20 30 35 40 45 50 55 60 65 70
DAYS POST INFECTION

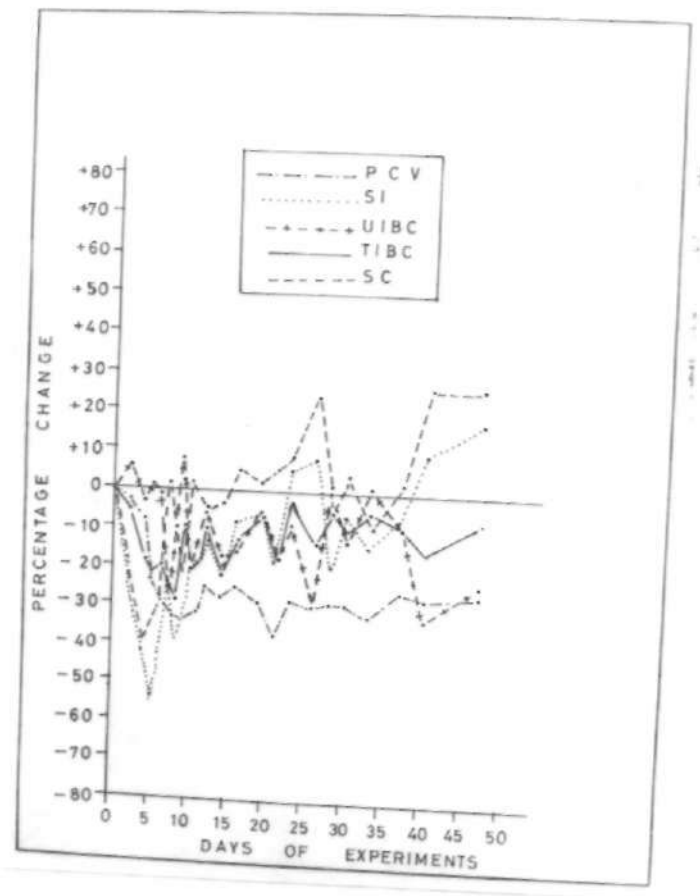
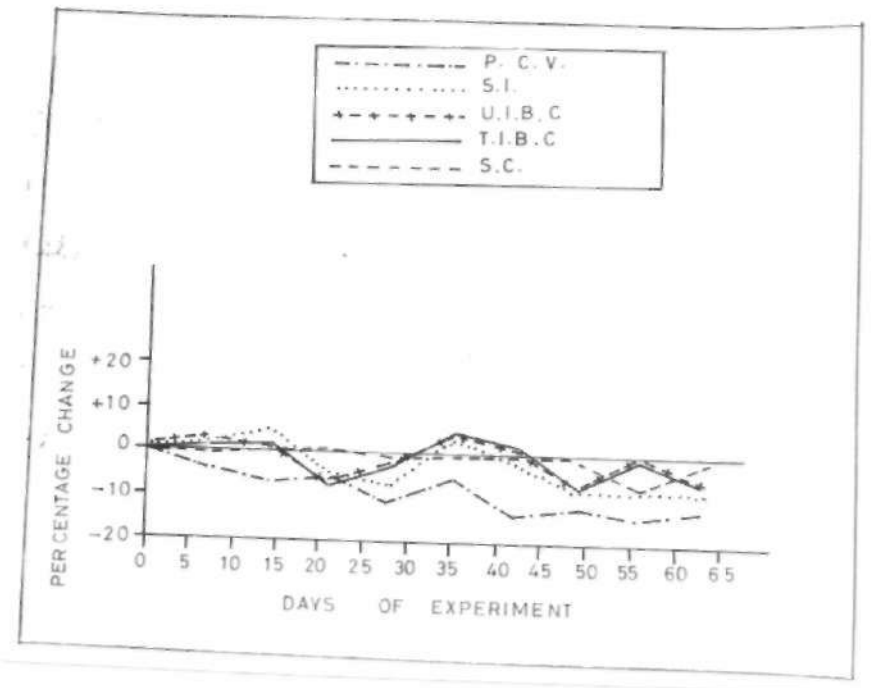

P C V
S I
U I B C
T I B C
S C
PERCENTAGE CHANGE
+80
+70
+60
+50
+40
+30
+20
+10
0
−10
− 20
− 30
− 40
− 50
−60
−70
−80
0 5 10 15 20 25 30 35 40 45 50
DAYS OF EXPERIMENTS

Fig. 7: Per cent changes from mean preexperimental values of packed cell volume (PCV), serum iron (SI), unbound iron-binding capacity (UIBC), total iron-binding capacity (TIBC) and per cent saturation of transferrin (SC) in uninoculated control cows.

Fig. 8: Per cent changes from mean preinfection values of packed cell volume (PCV), serum iron (SI), unbound iron-binding capacity (UIBC), total iron-binding capacity and per cent saturation of transferrin (SC) in cows infected with Trypanosoma vivax strain V953.


P. C. V.
S.I.
U.I.B.C
T.I.B.C
S.C.
PERCENTAGE CHANGE
+20
+10
0
-10
-20
0 5 10 15 20 25 30 35 40 45 50 55 60 65
DAYS OF EXPERIMENT

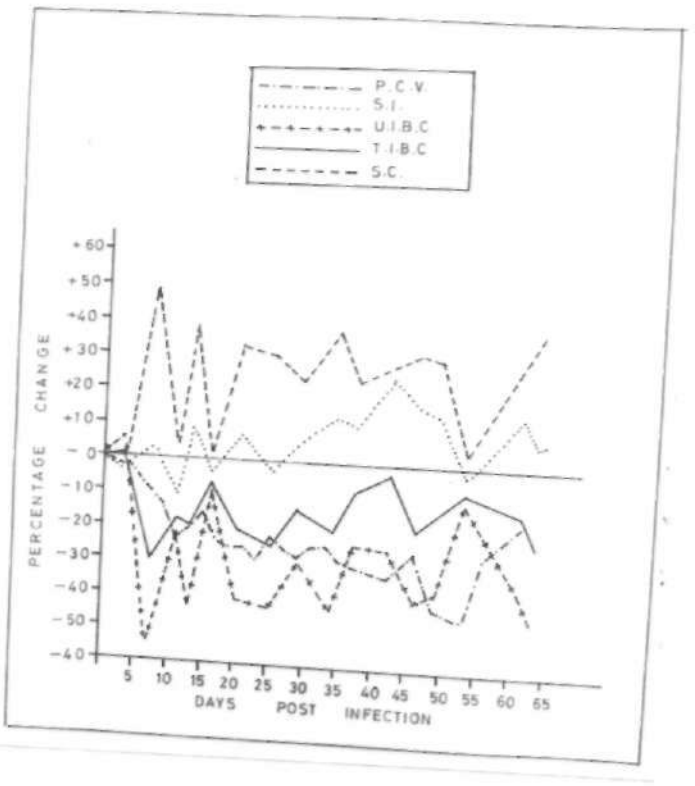
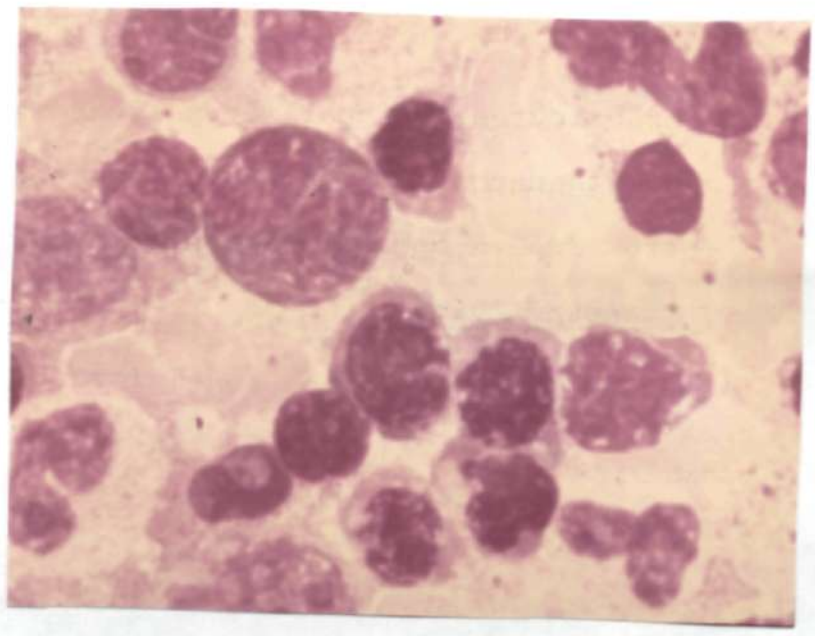

P.C.V.
S.I.
U.I.B.C
T.I.B.C
S.C.
PERCENTAGE CHANGE
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-40
5 10 15 20 25 30 35 40 45 50 55 60 65
DAYS POST INFECTION

Fig. 9: Prorubricytes, basophilic, polychromatic and orthochromatic rubricytes in bone marrow from a cow infected with Trypanosoma vivax. Giemsa stain X970.

Fig. 10: Nucleated erythrocytes and an eosinophil in bone marrow from a cow infected with Trypanosoma vivax. Giemsa stain X970.



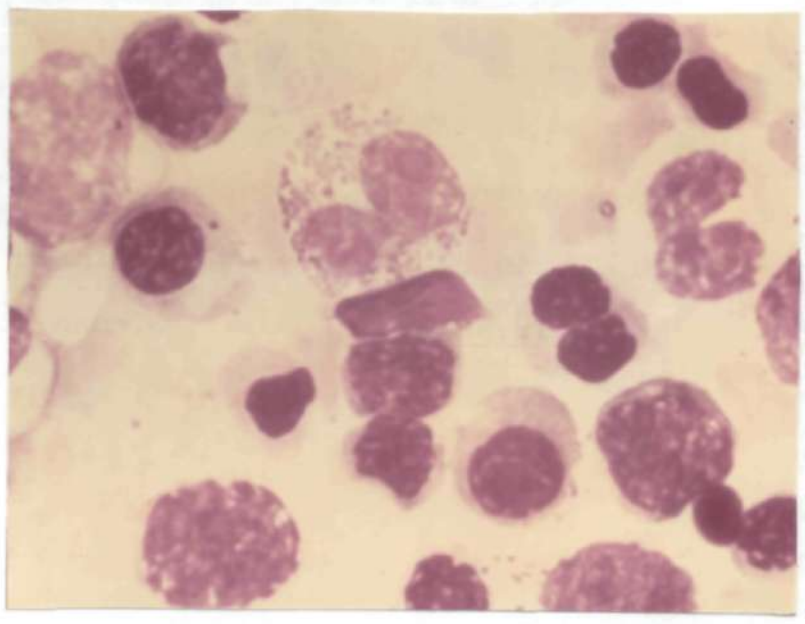
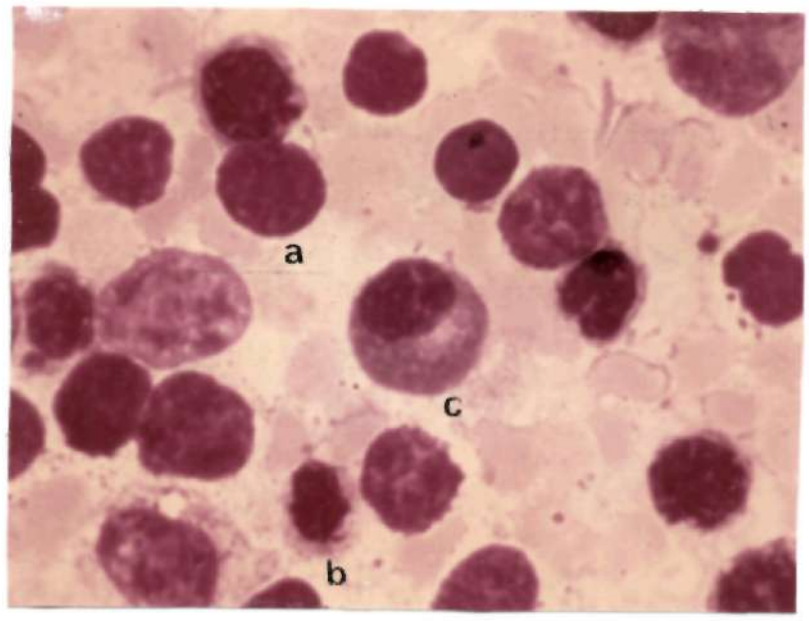


Fig. 11: Lymphocytes (1), nucleated erythrocytes (2) and a plasma cell (3) in bone marrow from a cow infected with Trypanosoma vivax. Giemsa stain X970.

Fig. 12: Mononuclear cell (1) with morphologic features of a plasma cell with numerous vacuoles in the cytoplasm. From the bone marrow of a cow infected with Trypanosoma vivax. Giemsa stain X970.


a
c
b

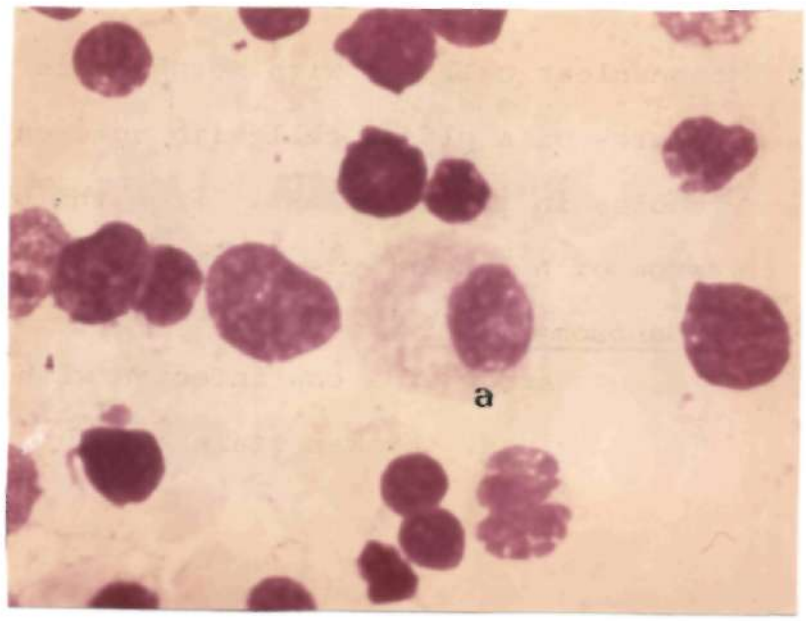
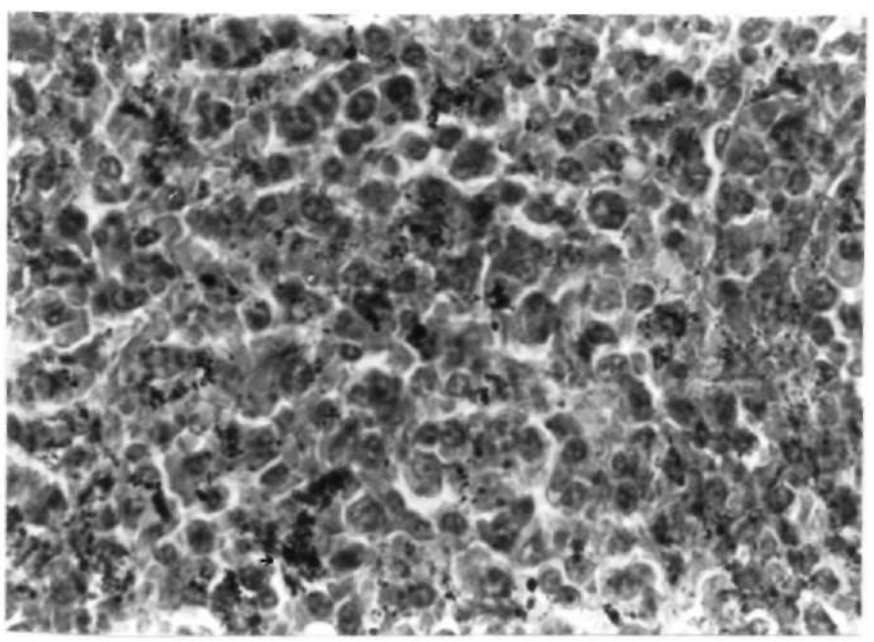
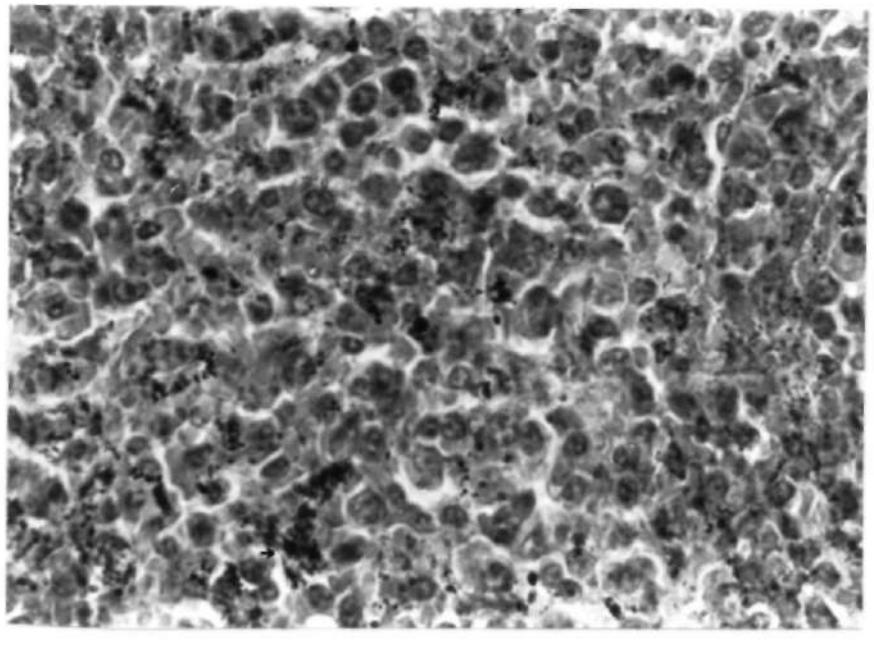

a

Fig. 13: Section of a spleen from a cow infected with Trypanosoma vivax. Many of the macrophages and reticuloendothelial cells contain haemosiderin. H & E X400.





# VIII: CLINICO-PATHOLOGIC FINDINGS IN ZEBU CATTLE EXPERIMENTALLY INFECTED WITH *TRYPANOSOMA CONGOLENSE*

## INTRODUCTION

Trypanosoma congolense infection in domestic animals is characterized by anaemia and chronic debilitation.

While a number of mechanisms have been proposed to explain the development of naemia (Fiennes, 1954; Naylor, 1971c; Losos et al., 1973; MacKenzie and Cruickshank, 1974; Wellde et al., 1974) there is no common agreement. The pathology of trypanosomiasis has been the subject of several recent reviews (Fiennes, 1970; Losos and Ikede, 1972; Murray, 1974; Ikede, 1975). This study provided further contribution on the clinico-pathologic aspects of the disease in cattle.

## MATERIALS AND METHODS

### Animals:

Three groups of apparently healthy Zebu cattle aged 1½ to 4 years were utilized. All cattle originated from known tsetse-fly-free areas of Nigeria. They were maintained in an animal holding shed and fed dried guinea corn stalks with leaves, hay and linted cotton seed mixed with ground guinea corn. They were observed for 2 weeks prior to the start of experiment. No mineral supplentation was provided. Water was provided ad libitum. All

cows were treated with Thiabendazole[a], Berenil[b] and Terramycin[c] 2 weeks prior to start of the experiments in an attempt to suppress concurrent infection.

Experimental Procedure:

Group 1 comprised of 5 cows (22, 23, 24, 25, 26) which were infected with a field strain of T. congolense. This strain (C3) was isolated from a naturally infected cow in Zaria. The isolate was maintained in mice through 4 passages before being transferred to a donor cow. Blood from the donor cow was used to infect 5 cows intravenously with 15 mls of heparinized blood containing 2,250 trypanosomes per $mm^3$. The cows (35, 36, 37, 38, 39) in group 2 were infected with a rat infective strain of T. congolense isolated from a natural bovine infection in Vom and maintained in rats. Each of the 5 cows was intravenously inoculated with 5 mls of heparinized blood from the donor rats containing approximately 12,750 trypanosomes per $mm^3$. Two cows (40, 41) in group 3 served as uninoculated controls. Trypanosome counts were carried out as in the T. vivax experiment.

Sampling:

The sampling techniques were the same as in T. vivax

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a Thiabendazole. Merck Sharp and Dohme Ltd; Hoddesdon, England.

b Berenil. Hoechst. Germany.

c Terramycin. Pfizer Corporation. Brussels, Belgium.

experiments except that plasma was collected instead of serum. Both experiments were terminated at 63 days post-infection. Cows that died or were euthanized were necropsied. Specimens of liver, spleen, lymph nodes, kidney and bone marrow were obtained and processed as in T. vivax experiment.

Haematology and Chemical Methods:

Techniques used were the same as in the T. vivax experiments.

## RESULTS

Clinical Signs and Parasitaemia:

All inoculated cows developed trypanosomiasis. A gradual deterioration in condition was observed following onset of patency and was characterized by lethargy, weakness, loss of weight, dull hair coats and pale mucous membranes. The cows maintained a good appetite except at times of anaemic crises or recumbency. There were periodic increases in rectal temperature.

The chronic course of trypanosomiasis was observed in all cows in group 1. One cow died at 60 days post-inoculation and 2 others died at 61 days post-inoculation following 2 days of recumbency. All infected cows developed parasitaemia 6 days post-inoculation. Parasitaemia was low but sustained throughout the period of

observation. No intercurrent infections were observed.

One cow in group 2 (No. 36) developed acute trypanosomiasis and died 21 days post-inoculation. The remaining cows developed chronic trypanosomiasis and survived until termination of the experiment. All cows developed parasitaemia 7 to 10 days post-inoculation. Parasitaemia was low and trypanosome counts were not determined after the 14th day post inoculation. A few trypanosomes were observed on blood smears throughout the experiments. No intercurrent infections were observed in any infected or control cows.

Haematological Findings:

Mean haematologic values of group 1 cows are presented in table 1. Individual cow data are presented in appendix 6. Haematologic values of the 2 control cows were presented in appendix 7. Cows in group 1 with chronic trypanosomiasis had a progressive decrease in Hb, RBC and PCV which began with the onset of patency. The changes in the erythrocyte parameters were accompanied by morphologic changes in erythrocytes. These included anisocytosis, polychromatophilia and punctate basophilias.

Percentage changes in total leukocytes, neutrophils and lymphocytes of infected cows are presented in Fig. 1. There was a persistent leukopenia with neutropenia and a relative lymphocytosis.

Mean haematologic values of group 2 cows are presented in table 2. Individual data are presented in appendix 6. One cow in this group (No. 36) which developed acute trypanosomiasis had a rapid decrease in erythrocyte values while the decrease was more gradual in cows with chronic trypanosomiasis. The peripheral blood morphologic changes were similar to group 1 cows.

Leukocyte alterations in group 2 cows were similar to those in group 1 (Fig. 2). Haematologic parameters of control cows remained within the normal range throughout the experiments.

Serum Iron and Iron-binding Capacity:

Mean PI, UIBC, TIBC and SC of cattle in group 1 are presented in table 3. Values for individual cows are presented in appendix 6. Percentage changes in PI, UIBC, TIBC, SC and PCV are presented in Fig. 3. Plasma iron decreased early in infection. The lowest PI was concomitant with the initial parasitaemia and pyrexia between 6 and 10 days post inoculation. Thereafter, PI gradually increased to normal. Periodic increases in PI were observed late in infection, usually in association with haemolytic episodes.

The UIBC decreased in all cows during the first 10 days of experiment. The decrease in UIBC and PI resulted

in a low SC. Following the initial decline in UIBC, there was a gradual increase. Changes in PI and UIBC resulted in marked alterations in SC (Fig. 3). In general, the SC was moderately increased during the period of infection. The lowest SC values were recorded early in infection when the PI was low. Low SC values were recorded at other times in association with rapid decreases in PI. Very high SC values were observed just prior to collapse and death.

Serum TIBC was generally low throughout the infection. The decrease in TIBC reflected the profound changes in PI and UIBC during the period of infection.

Mean PI, UIBC, TIBC and SC of cows in group 2 are presented in table 4. Percentage changes of these parameters from pre-infection mean are presented in Fig. 4. Individual cow data are presented in appendix 7.

The PI in all group 2 cows remained within the normal range except for a slight decrease which was observed between 10 and 14 days post infection.

The UIBC was low. This decrease resulted in high SC. The TIBC was low during the period of observation.

Bone Marrow Cytology:

Cytologic findings in bone marrow of cows in groups 1 and 2 were similar. There was marked erythropoiesis in

the bone marrow. Erythropoiesis was characterized by the presence of many developing erythrocytes. Rubricytes were increased while there were fewer metarubricytes (Fig. 5 and 6). Bone marrow cytologic findings are presented in table 5. Rubricytes were more numerous in infected than control cows. Granulocytopoiesis was observed. Many eosinophilic granulocytes were present (Fig. 7). Lymphocytes and plasma cells were present in varying numbers (Fig. 8). Erythrophagocytosis was observed in a few smears. Megakaryocytes were abundant.

Histologic Findings:

The histologic changes in groups 1 and 2 cows were similar. Hepatocytes were swollen and vacuolated and hepatic cords disorganized. Hepatic lipidosis was observed in one cow in which Fasciola gigantica was observed at necropsy. In the kidneys, there were many focal areas of mononuclear cell accumulation near the cortical glomeruli and around blood vessels in the cortex and upper medulla. Lymph nodes were hyperplastic. The macrophages contained haemosiderin. Spleens were congested and the medulla contained large numbers of lymphocytes and plasma cells (Fig. 9). Haemosiderosis was observed in all spleen sections from infected cows.

Bone marrow was packed with sheets of haematopoietic centres. Both developing granulocytes and erythrocytes were present. Many mononuclear cells, particularly lymphocytes and plasma cells, were observed. Megakaryocytes were abundant.

## DISCUSSION

Both strains of T. congolense used were pathogenic to adult Zebu cattle. The disease produced in infected cattle was predominantly chronic. Only one cow died of an acute infection. The severity of the disease varied in individual cows and was reflected by the changes in erythrocyte values. The differences in severity probably resulted from the virulence of the strains in individual hosts. The disease produced in infected cattle was similar to that reported by previous investigators (Fiennes et al., 1946; Fiennes, 1970; Kaliner, 1974; Naylor, 1971 a, b,; Losos and Ikede, 1972; Losos et al., 1973;.Wellde et al., 1974).

Initial patency developed later than in cattle infected with T. vivax. Parasitaemia was generally low but sustained.

Anaemia was the most significant feature of the disease. Anaemia developed within one week following

infection and was progressive. Morphologic alterations of erythrocytes included anisocytosis, polychromatophilia and basophilic stippling. These changes reflected the regenerative nature of the anaemia. In the absence of evidence of blood loss or erythrocyte lysis, it was concluded that the anaemia resulted from extravascular erythrocyte destruction. The marked haemosiderosis in the reticulo-endothelial organs and the occasional finding of erythrophagia in these organs suggested they were the primary sites of destruction. MacKenzie and Cruickshank (1973) observed intense erythrophagocytosis in the reticulo-endothelial system of sheep experimentally infected with T. congolense and suggested erythrophagocytosis was a major factor in development of anaemia. Jennings et al., (1974) reported rapid disappearance of $^{51}$Cr-labelled erythrocytes from circulation and a rapid removal of circulating $^{59}$Fe and its incorporation into erythrocytes. Their results suggested there was a shortened erythrocyte life span. Recent erythrokinetic studies in T. congolense infected Zebu cattle revealed that as the anaemia progressed there was a decrease in circulating erythrocytes mass. The decrease in circulating erythrocyte mass was associated with loss of $^{51}$Cr-

labelled red cells (Holmes and Mamo, 1975). These findings provide support for the suggestion that erythrocytes are removed from circulation and destroyed in the reticulo-endothelial system. The factors which pre-dispose the erythrocytes to be removed prematurely from the circulation for destruction in the reticulo-endothelial system are not well established but are believed to have an immunologic basis (Esuruoso, 1974; Murray, 1974).

There have been suggestions that intravascular haemolysis accounts, at least in part for the development of anaemia in trypanosomiasis (Fiennes, 1954; Wellde et al., 1974). Results of our studies did not support this concept. More definitive studies are required to establish the role of intravascular haemolysis in development of the anaemia.

It has been suggested that the early anaemia in cattle with trypanosomiasis arises in part from haemodilution (Fiennes, 1954). Holmes and Mamo (1975) observed that the decrease in circulating erythrocyte mass was associated with an over-compensatory increase in plasma volume. They suggested that the effect of haemodilution was of secondary importance in development

of anaemia. Hawkins et al., (1975) suggested that the early anaemia resulted from direct toxic action of trypanosomes upon the blood. Further studies are required to establish the factors involved in the early development of anaemia in bovine trypanosomiasis.

The results of serum iron studies indicated that iron-deficiency was not a feature of the anaemia. The absence of protracted hyperferremia in the course of disease suggested that intravascular haemolysis was not a significant factor in the development of anaemia. The alterations in UIBC, TIBC and SC reflected the changes in SI plasma volume that accompanied the disease. The changes observed were similar to those reported by Tartour and Idris (1973) in T. congolense infected cattle.

## SUMMARY

Two groups of apparently healthy Zebu cattle were inoculated with 2 strains of T. congolense. All inoculated cattle developed trypanosomiasis. Anaemia was the principal pathologic feature of the disease. The onset of anaemia coincided with initial parasitaemia, which was low. The course of disease was predominantly chronic and was characterized by a progressively

developing anaemia. Morphologic alterations of erythrocytes included anisocytosis, polychromatophilia and basophilic stippling. Bone marrow of infected cows was regenerative. Iron deficiency was not a feature of the disease. It was concluded that like in T. vivax infected cattle, anaemia resulted from accelerated erythrocyte destruction in the reticuloendothelial system.

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Table 1 : Means and standard deviations of PCV, Hb and total leukocytes in 4 cows experimentally infected with T. congolense, strain C3.

| Days of Expt | PCV % | Hb gm/dl | WBC |
|---|---|---|---|
| -1 | 31.8 ± 4.4 | 10.5 ± 1.8 | 10983 ± 3024 |
| 0 | 31.0 ± 2.9 | 10.1 ± 1.2 | 10133 ± 3237 |
| 4 | 32.0 ± 3.6 | 10.9 ± 0.9 | 8850 ± 2020 |
| 7 | 29.8 ± 3.6 | 9.8 ± 1.1 | 7712 ± 3191.8 |
| 10 | 28.0 ± 4.3 | 9.1 ± 1.6 | 8550 ± 2633.4 |
| 14 | 26.8 ± 4.9 | 8.7 ± 1.8 | 8512.5 ± 4740.0 |
| 17 | 26.8 ± 4.2 | 8.7 ± 1.1 | 10375.0 ± 812.9 |
| 21 | 21.3 ± 3.3 | 6.8 ± 0.9 | 8412.5 ± 4010.7 |
| 24 | 19.3 ± 2.6 | 6.0 ± 0.9 | 7662.5 ± 2675.3 |
| 28 | 19.3 ± 0.9 | 5.8 ± 1.0 | 9425.0 ± 3430.4 |
| 31 | 20.5 ± 1.3 | 6.8 ± 0.3 | 9400.0 ± 3247.3 |
| 35 | 20.5 ± 1.3 | 6.5 ± 0.7 | 8950.0 ± 2963.4 |
| 39 | 20.8 ± 2.9 | 6.9 ± 1.0 | 9662.5 ± 4071.5 |
| 42 | 20.0 ± 2.6 | 7.0 ± 0.7 | 12650.0 ± 3745.3 |
| 45 | 21.0 ± 4.2 | 7.0 ± 1.1 | 8975.0 ± 2663.5 |
| 49 | 19.8 ± 5.3 | 6.6 ± 1.7 | 6925.0 ± 2006.9 |
| 52 | 18.5 ± 3.5 | 5.6 ± 1.2 | 8612.5 ± 2154.2 |
| 56 | 21.3 ± 5.6 | 6.9 ± 1.9 | 7875.0 ± 2146.9 |
| 59 | 20.3 ± 6.5 | 6.4 ± 2.4 | 11125.0 ± 5056.6 |
| 63 | 21.3 ± 6.9 | 6.8 ± 2.5 | 9487.5 ± 3805.8 |

Table 2: *Means and standard deviations of rectal temperature, Packed cell volume, Haemoglobin, Erythrocytes and total leukocytes in Zebu cattle experimentally infected with T. congolense. Vom strain.*

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | W B C | Temp. °C |
|---|---|---|---|---|---|
| -8 | 30.6 ± 3.1 | 10.6 ± 1.1 | 6.66 ± 0.65 | 11080 ± 3432 | 38.7 |
| -6 | 31.2 ± 3.5 | 10.8 ± 1.1 | 6.58 ± 1.34 | 10570 ± 3847 | 38.6 |
| 0 | 29.0 ± 1.6 | 9.5 ± 0.7 | 6.24 ± 0.91 | 11150 ± 4061 | 38.6 |
| 3 | 28.4 ± 1.5 | 9.4 ± 0.6 | 7.03 ± 0.86 | 9590 ± 3403 | 38.7 |
| 4 | 27.4 ± 2.7 | 9.5 ± 1.0 | 6.62 ± 0.87 | 9600 ± 3771 | 38.9 |
| 6 | 29.0 ± 3.4 | 9.7 ± 1.1 | 6.16 ± 0.97 | 6910 ± 1209 | 39.3 |
| 7 | 28.6 ± 4.0 | 9.5 ± 1.6 | 6.51 ± 1.45 | 7300 ± 2676 | 39.7 |
| 8 | 27.8 ± 3.6 | 9.1 ± 1.3 | 5.82 ± 1.10 | 7540 ± 2806 | 39.6 |
| 9 | 26.2 ± 3.1 | 8.6 ± 1.3 | 5.93 ± 1.08 | 8350 ± 1229 | 39.2 |
| 10 | 27.2 ± 2.7 | 8.9 ± 0.4 | 5.96 ± 0.78 | 7130 ± 2900 | 39.7 |
| 11 | 25.8 ± 1.3 | 8.8 ± 0.4 | 6.32 ± 0.84 | 7420 ± 2046 | 38.4 |
| 14 | 23.2 ± 1.3 | 7.3 ± 0.5 | 6.42 ± 0.53 | 6660 ± 2360 | 38.4 |
| 17 | 22.0 ± 2.1 | 7.3 ± 0.5 | 5.23 ± 0.71 | 7860 ± 2186 | 39.1 |
| 19 | 20.6 ± 2.4 | 6.8 ± 0.9 | 4.23 ± 0.76 | 6460 ± 2984 | 38.9 |
| 21 | 20.2 ± 1.6 | 6.6 ± 0.7 | 4.66 ± 0.60 | 10160 ± 4117 | 39.0 |
| 24 | 19.4 ± 2.4 | 6.7 ± 0.9 | 4.42 ± 1.32 | 7542 ± 3182 | 39.1 |
| 26 | 19.4 ± 2.6 | 6.1 ± 1.1 | 3.86 ± 0.81 | 7650 ± 2320 | 39.4 |
| 28 | 19.2 ± 1.5 | 5.9 ± 0.4 | 4.09 ± 0.83 | 9340 ± 4602 | 39.1 |
| 32 | 18.4 ± 2.7 | 5.7 ± 0.8 | 3.95 ± 1.01 | 8140 ± 2908 | 39.0 |
| 34 | 19.4 ± 1.1 | 5.8 ± 0.3 | 4.25 ± 0.53 | 8580 ± 2307 | 39.0 |
| 48 | 19.0 ± 1.2 | 5.8 ± 0.5 | 4.21 ± 0.63 | 8550 ± 3483 | 39.0 |
| 42 | 17.6 ± 1.5 | 5.3 ± 0.6 | 3.76 ± 0.57 | 7690 ± 3661 | 39.0 |
| 45 | 17.0 ± 1.6 | 5.5 ± 0.6 | 3.48 ± 0.41 | 7910 ± 3260 | 38.9 |
| 48 | 15.2 ± 1.9 | 4.4 ± 1.0 | 2.90 ± 0.26 | 8720 ± 3970 | 38.9 |
| 51 | 14.6 ± 1.8 | 4.3 ± 0.7 | 2.58 ± 0.50 | 7620 ± 3802 | 39.3 |
| 54 | 15.2 ± 2.4 | 4.0 ± 0.9 | 3.09 ± 1.02 | 8770 ± 2565 | 38.9 |
| 58 | 15.2 ± 3.0 | 4.6 ± 1.2 | 2.80 ± 0.64 | 9020 ± 2415 | 38.7 |
| 60 | 13.8 ± 2.2 | 4.2 ± 0.8 | 2.81 ± 0.96 | 8910 ± 2356 | 38.8 |

Table 3 : Means and standard deviations of PI, UIBC, TIBC and SC in four cows experimentally infected with Trypanosoma congolense. strain C3.

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 114.4 ± 24.4 | 85.6 ± 28.5 | 200.0 ± 49.5 | 57.6 ± 5.6 |
| -1 | 102.5 ± 17.2 | 131.3 ± 10.9 | 233.8 ± 11.1 | 43.7 ± 5.7 |
| 0 | 110.6 ± 17.0 | 125.4 ± 24.9 | 236.0 ± 35.9 | 47.1 ± 4.6 |
| 4 | 120.0 ± 27.0 | 108.8 ± 10.1 | 228.8 ± 29.8 | 52.1 ± 6.0 |
| 7 | 115.3 ± 37.1 | 110.4 ± 50.4 | 220.6 ± 30.7 | 53.0 ± 18.8 |
| 10 | 96.3 ± 19.8 | 123.5 ± 21.8 | 220.5 ± 41.0 | 43.6 ± 2.4 |
| 14 | 85.0 ± 17.8 | 103.8 ± 17.9 | 188.8 ± 17.0 | 45.0 ± 8.4 |
| 17 | 116.3 ± 28.4 | 99.1 ± 37.7 | 215.4 ± 31.7 | 54.7 ± 15.5 |
| 21 | 108.8 ± 25.0 | 116.6 ± 15.8 | 225.4 ± 23.3 | 47.9 ± 8.5 |
| 24 | 110.0 ± 17.9 | 49.9 ± 11.8 | 159.9 ± 17.4 | 68.7 ± 6.8 |
| 28 | 120.6 ± 2.4 | 73.9 ± 27.4 | 194.5 ± 25.4 | 62.9 ± 9.4 |
| 31 | 147.3 ± 53.1 | 84.4 ± 50.8 | 231.6 ± 44.5 | 63.9 ± 17.9 |
| 35 | 98.8 ± 20.6 | 125.4 ± 62.6 | 224.4 ± 62.1 | 46.3 ± 15.7 |
| 39 | 114.8 ± 9.0 | 117.3 ± 28.6 | 232.0 ± 36.1 | 49.9 ± 4.6 |
| 42 | 93.4 ± 28.7 | 131.9 ± 41.2 | 226.5 ± 44.1 | 42.1 ± 13.4 |
| 45 | 123.4 ± 37.8 | 96.5 ± 50.7 | 220.0 ± 30.4 | 57.2 ± 20.2 |
| 49 | 110.4 ± 24.8 | 103.8 ± 19.6 | 214.1 ± 14.8 | 51.4 ± 10.1 |
| 52 | 101.6 ± 14.5 | 101.3 ± 24.2 | 202.9 ± 30.3 | 50.8 ± 6.6 |
| 56 | 136.9 ± 16.3 | 114.4 ± 30.7 | 251.3 ± 20.9 | 54.9 ± 9.2 |
| 59 | 156.1 ± 68.4 | 159.3 ± 56.5 | 315.5 ± 65.4 | 47.1 ± 15.9 |
| 63 | 160.0 ± 34.3 | 119.3 ± 33.3 | 248.8 ±100.2 | 54.9 ± 4.8 |

Table 4 : Means and standard deviation of plasma iron, unbound iron-binding capacity, total iron-binding capacity and percentage saturation of transferrin in five Zebu cows experimentally infected with T. congolense Vom strain.

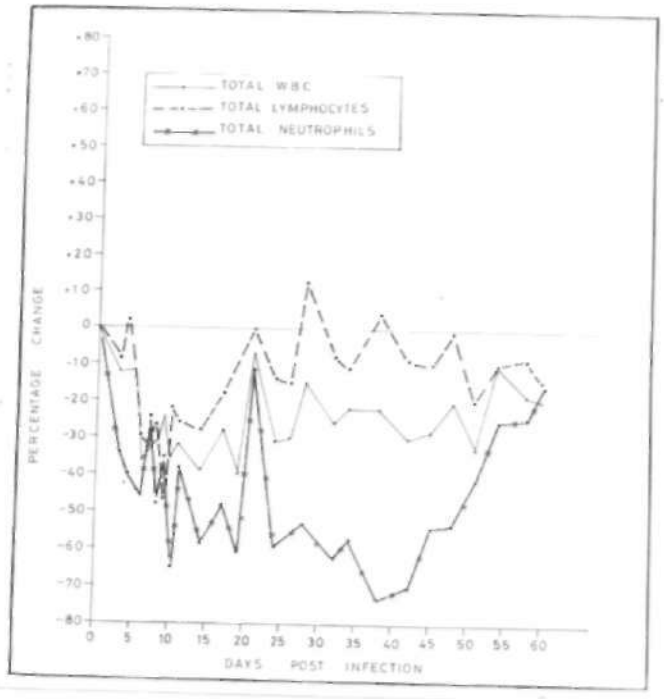
| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 82.8 ± 21.9 | 123.6 ± 44.8 | 206.4 ± 64.1 | 40.5 ± 4.5 |
| -2 | 86.8 ± 31.3 | 139.4 ± 32.0 | 226.2 ± 43.4 | 37.9 ± 10.8 |
| 0 | 81.0 ± 22.8 | 96.0 ± 15.5 | 187.0 ± 32.9 | 48.4 ± 7.3 |
| 3 | 85.4 ± 25.6 | 93.0 ± 14.4 | 178.4 ± 34.9 | 47.1 ± 7.7 |
| 6 | 59.2 ± 24.5 | 131.8 ± 21.2 | 191.0 ± 30.1 | 30.4 ± 9.6 |
| 10 | 72.4 ± 47.8 | 85.0 ± 44.2 | 157.4 ± 15.6 | 45.3 ± 29.8 |
| 14 | 85.2 ± 23.1 | 72.5 ± 51.2 | 157.2 ± 42.4 | 58.8 ± 25.8 |
| 17 | 85.4 ± 13.6 | 86.3 ± 17.5 | 169.4 ± 24.4 | 50.5 ± 5.1 |
| 19 | 94.4 ± 21.8 | 74.0 ± 20.1 | 172.0 ± 28.9 | 54.6 ± 6.6 |
| 21 | 91.6 ± 17.5 | 91.0 ± 19.8 | 182.6 ± 37.3 | 50.5 ± 1.4 |
| 24 | 84.0 ± 33.2 | 96.0 ± 27.9 | 180.0 ± 45.1 | 46.6 ± 11.9 |
| 26 | 82.6 ± 11.9 | 108.0 ± 20.2 | 190.4 ± 20.6 | 43.5 ± 6.8 |
| 28 | 88.6 ± 27.1 | 140.0 ± 56.1 | 228.6 ± 61.1 | 39.9 ± 15.1 |
| 32 | 91.0 ± 6.1 | 128.0 ± 65.6 | 219.0 ± 67.5 | 42.7 ± 13.1 |
| 34 | 93.0 ± 21.3 | 101.0 ± 23.0 | 194.0 ± 20.1 | 48.1 ± 10.2 |
| 38 | 88.0 ± 19.6 | 120.0 ± 36.4 | 208.6 ± 32.2 | 43.4 ± 13.4 |
| 42 | 86.4 ± 32.1 | 114.0 ± 31.3 | 195.4 ± 23.4 | 41.4 ± 15.8 |
| 45 | 87.4 ± 39.7 | 163.0 ± 80.9 | 250.4 ± 53.3 | 36.4 ± 21.5 |
| 48 | 148.6 ± 89.4 | 130.0 ± 63.4 | 252.0 ± 53.8 | 51.6 ± 22.1 |
| 51 | 117.8 ± 13.4 | 157.4 ± 57.3 | 275.2 ± 58.1 | 44.2 ± 9.6 |
| 54 | 134.2 ± 43.9 | 56.0 ± 50.7 | 190.2 ± 56.8 | 72.7 ± 23.5 |
| 58 | 104.8 ± 48.2 | 41.4 ± 47.8 | 164.4 ± 38.6 | 76.2 ± 28.9 |
| 60 | 101.8 ± 42.2 | 44.4 ± 36.5 | 160.2 ± 39.9 | 72.3 ± 22.2 |

Table 5: Per cent distribution of nucleated erythrocytes in bone marrow of cows infected with Trypanosoma vivax, Trypanosoma congolense compared to uninoculated controls.

| Animal No. | Infected with | Percentage distribution | | | Metarubricyte |
|---|---|---|---|---|---|
| | | Rubriblast | Prorubricyte | Rubricyte | |
| 14 | T. vivax | 0.5 | 5.0 | 58.0 | 36.5 |
| 15 | T. vivax | 0.9 | 1.8 | 75.0 | 22.0 |
| 31 | T. Vivax | 0.0 | 2.0 | 61.5 | 36.5 |
| 32 | T. vivax | 0.0 | 4.8 | 47.5 | 47.7 |
| Mean & SD | T. vivax | 0.35 ± 0.4 | 3.4 ± 1.7 | 60.5±1.4 | 35.7 ± 0.5 |
| 22 | T. congolense | 3.5 | 14.0 | 67.5 | 15.0 |
| 25 | T. congolense | 0.0 | 4.3 | 52.0 | 43.7 |
| 26 | T. congolense | 2.5 | 7.0 | 67.0 | 23.5 |
| 37 | T. congolense | 0.0 | 1.0 | 67.0 | 32.0 |
| 39 | T. congolense | 0.0 | 3.5 | 78.8 | 17.7 |
| Mean & SD | T. congolense | 1.2 ± 1.7 | 6.0 ± 5.0 | 66.5±9.5 | 26.4 ± 11.7 |
| Controls | - | 1.4 ± 0.6 | 3.5 ± 1.9 | 39.3±5.0 | 55.8 ± 4.1 |

Fig. 1: Per cent changes from mean preinfection values of total leukocytes (WBC), lymphocytes and neutrophils of cows infected with Trypanosoma congolense strain C3.

Fig. 2: Per cent changes from mean preinfection values of total leukocytes (WBC), lymphocytes and neutrophils of cows infected with Trypanosoma congolense strain Vom.


TOTAL WBC
TOTAL LYMPHOCYTES
TOTAL NEUTROPHILS
PERCENTAGE CHANGE
+80
+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
0 5 10 15 20 25 30 35 40 45 50 55 60
DAYS POST INFECTION

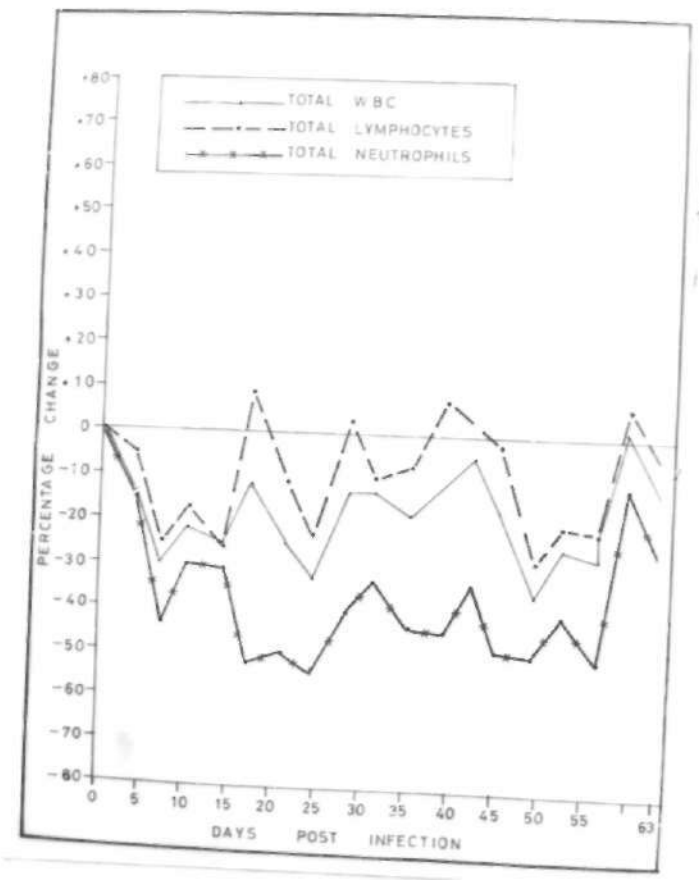
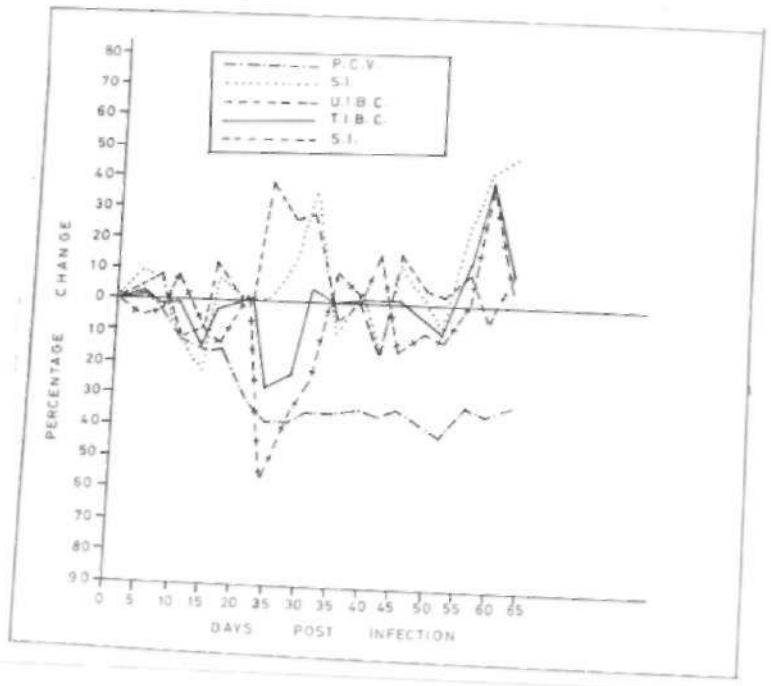

TOTAL WBC
TOTAL LYMPHOCYTES
TOTAL NEUTROPHILS
PERCENTAGE CHANGE
+80
+70
+60
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
-60
-70
-80
0 5 10 15 20 25 30 35 40 45 50 55 63
DAYS POST INFECTION

Fig. 3: Per cent changes from mean preinfection values of packed cell volume (PCV), plasma iron (SI), unbound iron-binding capacity (UIBC), total iron-binding capacity (TIBC) and per cent saturation of transferrin (SC) in cows infected with Trypanosoma congolense strain C3.

Fig. 4: Per cent changes from mean preinfection values of packed cell volume (PCV), plasma iron (SI), unbound iron-binding capacity (UIBC), total iron-binding capacity (TIBC) and per cent saturation of transferrin (% Sat.) in cows infected with Trypanosoma congolense strain Vom.


P.C.V.
S.I.
U.I.B.C.
T.I.B.C.
S.I.
PERCENTAGE CHANGE
DAYS POST INFECTION

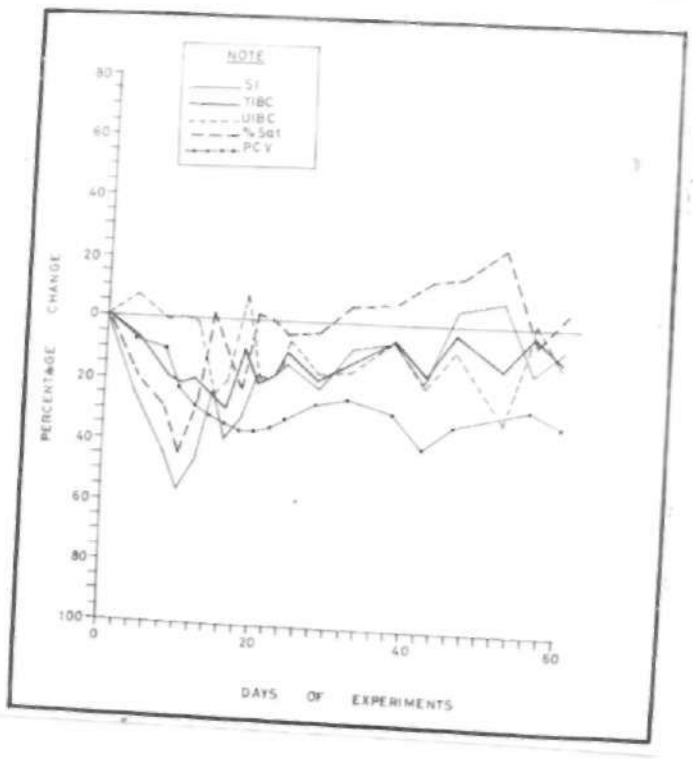
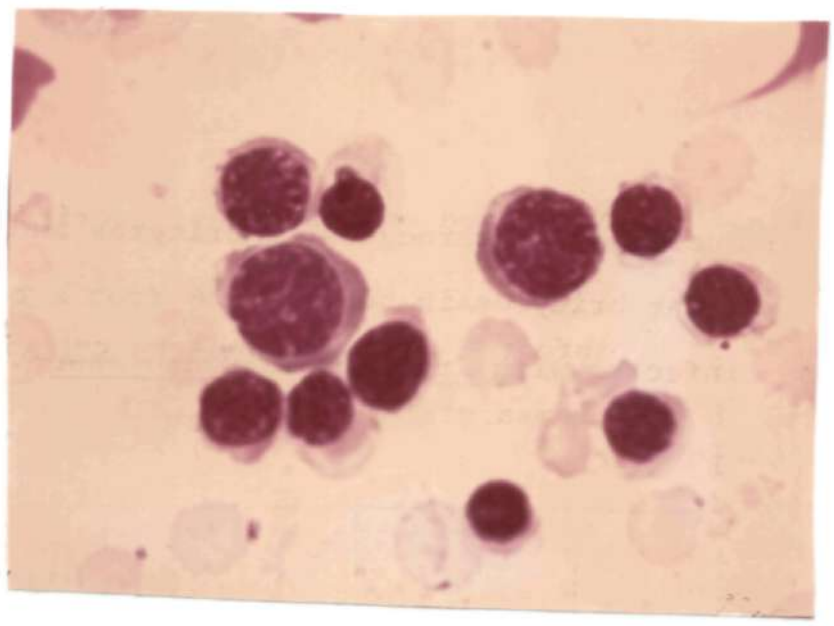

NOTE
SI
TIBC
UIBC
% Sat
PCV
PERCENTAGE CHANGE
DAYS OF EXPERIMENTS

Fig. 5: Nucleated erythrocytes, rubricytes and metarubricytes in bone marrow from a cow infected with Trypanosoma congolense. Giemsa stain X970.

Fig. 6: Dividing rubricyte (1) and other nucleated erythrocytes in bone marrow of a cow infected with Trypanosoma congolense. Giemsa stain X970.



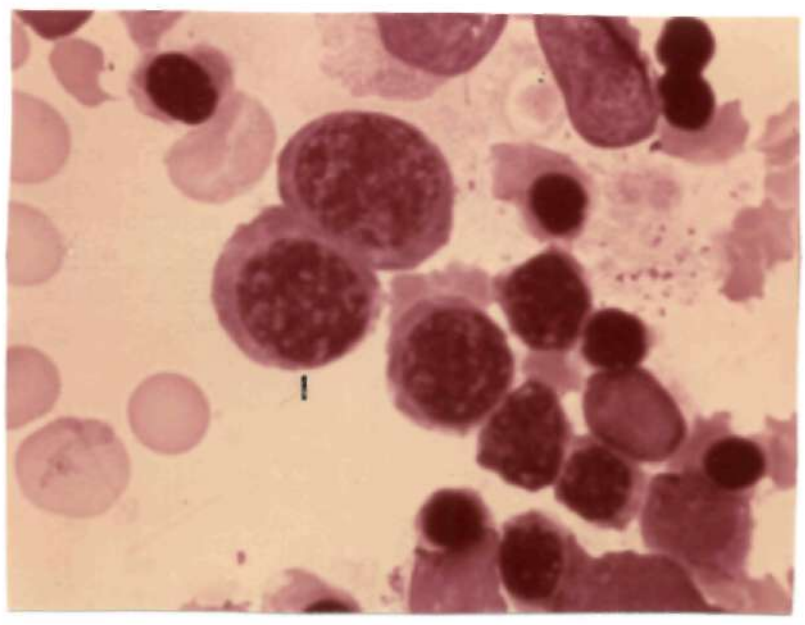
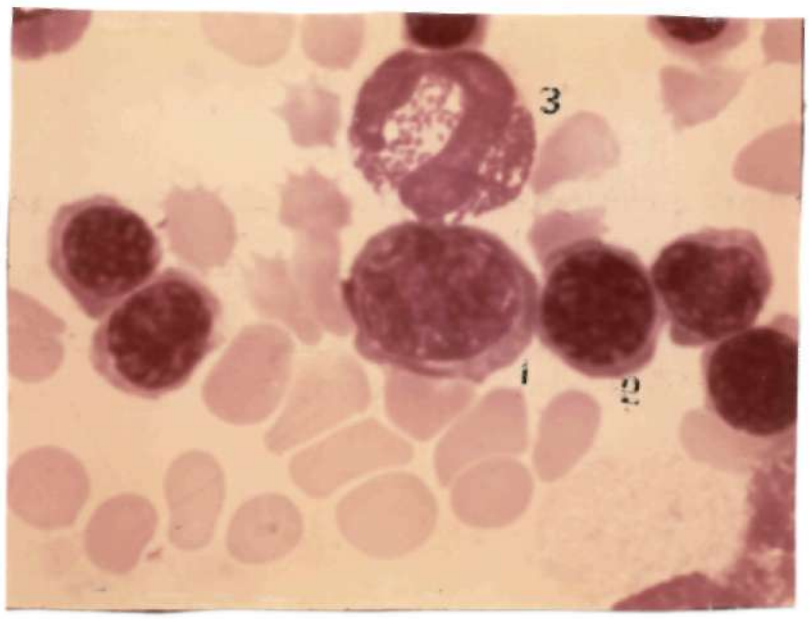


Fig. 7: Late prorubricyte (1), rubricytes (2) and an eosinophil (3) in bone marrow from a cow infected with Trypanosoma congolense. Giemsa stain X970.

Fig. 8: Progranulocyte (1), neutrophilic myelocyte (2), plasma cell (3) and nucleated erythrocytes in bone marrow from a cow infected with Trypanosoma congolense. Giemsa stain X970.


3
1
2

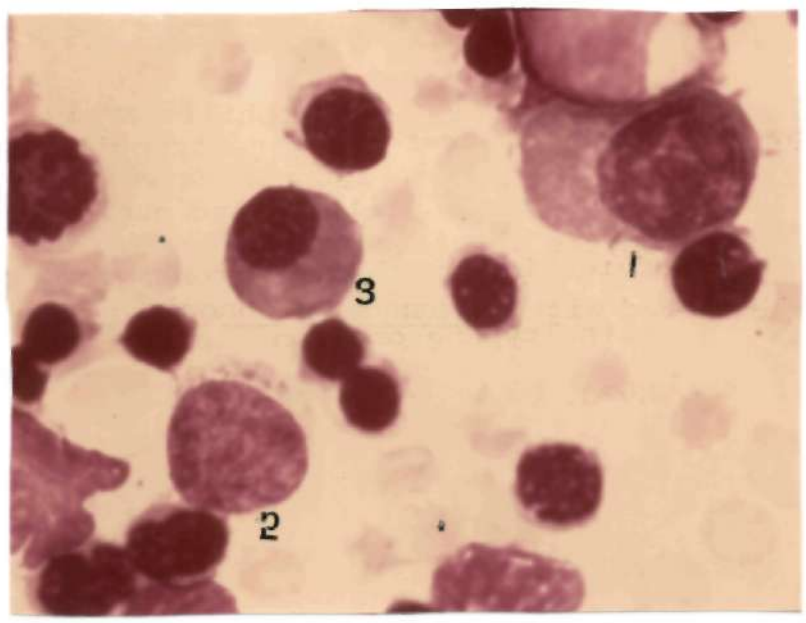
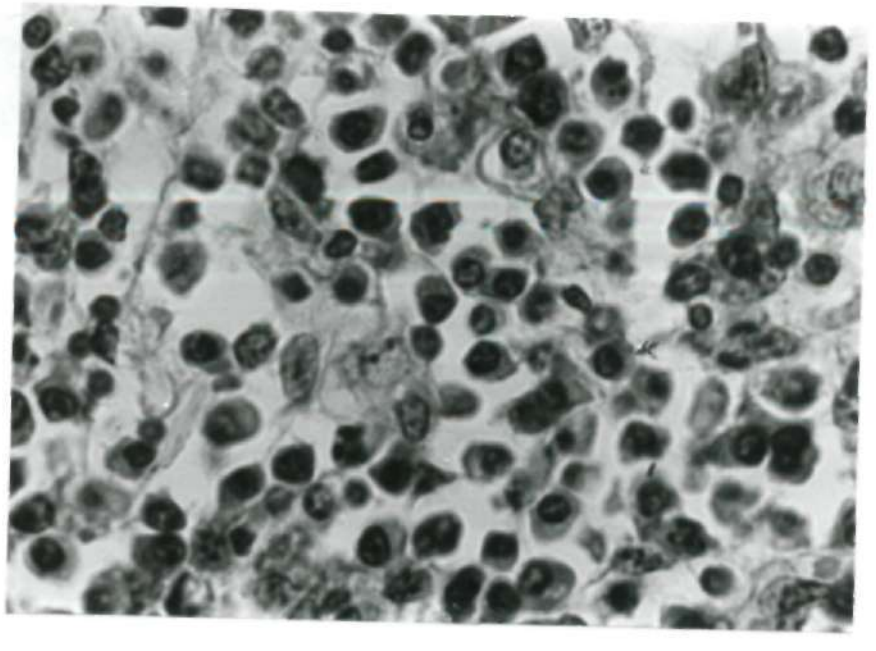

3
1
2

Fig. 9: Numerous lymphocytes and plasma cells in medulla of a spleen from a cow infected with Trypanosoma congolense. H & E X400.



# IX: CLINICOPATHOLOGIC FINDINGS IN ZEBU CATTLE WITH EXPERIMENTAL *T. VIVAX* AND *T. CONGOLENSE* INFECTION: GENERAL DISCUSSION

Haematologic, pathologic and chemical changes in native Zebu cattle experimentally infected with T. vivax and T. congolense were investigated.

Clinical manifestations of trypanosomiasis in cattle produced by these trypanosomes were similar. Clinical signs included intermittent pyrexia, weight loss, debilitation, weakness and anaemia. The course of trypanosomiasis varied in individual animals and may have been influenced by the virulence of the infecting trypanosomes, the hosts' ability to withstand the infection and the presence of intercurrent blood parasitic infections.

Trypanosomiasis was characterized by high morbidity but low mortality. Animals that succumbed to the infection usually had concurrent infections. The principal offenders were Babesia bigemina and Anaplasma marginale. These were probably latent infections triggered off by the debilitating effects of trypanosomiasis and contributed to the development of anaemia and deaths.

High mortality rates have been reported in Zebu cattle introduced into heavy tsetse-infested areas (Van Hoeve, 1971). Results of this study suggest that Zebu cattle could withstand a single first trypanosomiasis infection. Thus Zebu cattle in the field may

withstand moderate exposure to trypanosomiasis, particularly, under higher standards of management and nutrition including control of ticks and tick-borne diseases.

It is widely held that bovine trypanosomiasis is one of the principal factors restricting development of livestock industry in Nigeria (Leeflang, 1974). However, babesiosis, anaplasmosis and heartwater probably directly or indirectly account for greater number of cattle deaths than is commonly recognized. That the threat posed by these parasites to the growth of livestock is not widely appreciated may be seen in the little attention paid to the problem of tick control (vectors of these parasites) and tick-borne diseases.

T. vivax showed a higher degree of parasitaemia than T. congolense in Zebu cattle. The difference in times of initial patency following experimental infection and the degree of parasitaemia between T. vivax and T. congolense was probably related to the numbers of infecting trypanosomes and the biologic characteristics of these trypanosomes in the bovine host. The initial peak parasitaemia was associated with high fevers in both T. vivax and T. congolense infected cattle.

All infected cattle had a pattern of repeated build up and decline in the number of trypanosomes in the circulation with higher peaks observed early in disease. This intermittent pattern of high and low parasitaemia may be related to the development of antigenic variants by these trypanosomes (Wilson and Cunningham, 1970, 1972; Seed, 1974, and Jones, 1975). It may be that as parasites build up in the circulation, specific antibodies are produced by the host against surface antigens of the organism. These antibodies might subsequently destroy the organisms, thus decreasing their numbers in circulation sufficiently that trypanosomes are no longer detectable by conventional diagnostic methods. The few surviving trypanosomes could then acquire new surface antigens and multiply unimpeded until the host mounts another immunologic attack. Further studies are required to determine the biology of trypanosomes in cattle and elucidate factors that account for this phenomenon. This variation in circulating parasites poses diagnostic problems. Common laboratory methods used to detect the presence of trypanosomes may give false negative results when numbers of trypanosomes in the circulation are on the wane. The need to devise more accurate diagnostic methods is self evident.

Anaemia was the principal pathologic feature of T. vivax and T. congolense infection in cattle. Development of anaemia was similar in most cows. Following initial patency, there was a progressive decrease in PCV, Hb and RBC which continued until some cows succumbed in anaemic crisis. In cows that survived, there was a gradual increase in PCV, Hb and RBC that began 4 to 6 weeks post infection but these values never returned to pre-infection levels. Similar pattern of development of anaemia has been reported in cattle (Fiennes, 1954; 1970; Naylor, 1971a,b,c; Losos et al., 1973; Wellde et al., 1974) and in sheep and goats, (Edwards et al., 1956).

Anaemia may be defined as a reduction below normal in RBC, PCV and Hb. Although there are many ways to classify anaemias, classification based on causes is most suitable for cattle as anisocytosis is a common feature of normal bovine blood. Etiologically, bovine anaemia may be summarised as follows:

1. Anaemia due to increased erythrocyte destruction.
   a) acute or chronic post haemorrhagic anaemia due to internal or external blood loss.
   b) Haemolytic anaemia due to toxins, infectious diseases (bacterial, viral and protozoan),

immunohaemolytic anaemias and haemolytic anaemias of unknown origin.

2. Anaemias due to decreased erythrocyte production. These may result from nutritional deficiencies (Fe, cobalt, copper, protein etc.), bone marrow failure or impaired erythropoietin production.

In these experiments there was no evidence of internal or external haemorrhage and therefore it is unlikely that the anaemia resulted from acute or chronic blood loss.

Our results further suggest that the anaemia of trypanosomiasis was not of nutritional origin. All cows maintained a good appetite and were on diets that were clearly better than average for native Zebu cattle. Although serum cobalt was not determined, evaluation of serum iron and copper revealed no deficiency in these elements (Saror, 1975). Previous studies by French and Hornby (1938) also demonstrated that the anaemia of trypanosomiasis had no nutritional basis.

There have been suggestions that bone marrow hypoplasia was a factor in producing the anaemia in chronic trypanosomiasis (French and Hornby, 1938; Fiennes, 1970; Losos et al., 1973). Bone marrow hypoplasia was not

demonstrated in any of our experimental cows. While bone marrow hypoplasia may play a role in the development of anaemia in chronically infected cattle, it did not appear to have done so in the anaemia that occurred in the first 9 weeks of infection. Evidence for this comes from the finding of marked erythropoiesis in all cows that died acutely or were euthanized after 9 weeks of infection.

It is now recognized that decreased erythropoietin is a deterrent to normal erythropoiesis (Wilson and Walter, 1952). Anaemias associated with decreased erythropoietin stimulus resulted from a reduction in tissue oxygen need or kidney diseases that impaired the ability of this organ to produce erythropoietin (Finch et al., 1970). Undoubtedly the anaemia that developed in trypanosomiasis was accompanied by increased tissue oxygen need. There was no renal pathology of the magnitude that could reduce the ability of the kidney to produce erythropoietin. Although plasma erythropoietin values were not determined, the absence of severe renal disease and the active erythropoiesis in the bone marrows suggested that the kidneys were functionally capable of erythropoietin production. It may thus be concluded that the anaemia of bovine trypanosomiasis in these

experimental infections of 9 weeks duration did not result from iron deficiency, impaired erythropoietin production or marrow failure.

Anisocytosis, polychromatophilia, basophilic stippling and reticulocytosis were observed in experimentally infected cows. These morphologic changes were indicative of regenerative anaemia. However, the regenerative process as evaluated from peripheral blood was not commensurate with the degree of anaemia or the erythrogenetic activity in the bone marrow. Cytologic examination of marrow revealed numerous developmental forms of erythrocytes particularly basophilic, polychromatic and orthochromatic rubricytes. There were relatively fewer metarubricytes. Histologically, bone marrows were solidly packed with developing erythrocytes and granulocytes. The presence of active erythropoiesis in the bone marrow but relatively few peripheral blood changes reflective of the bone marrow activity suggested the possibility of:-

1. interrupted maturation sequence in the erythrocyte series at the metarubricyte level.
2. inadequate release of young erythrocytes from the bone marrow to peripheral circulation.

3. premature destruction of young (probably defective) erythrocytes in the bone marrow or a combination of these mechanisms.

Further studies of morphologic and biochemical characteristics of bone marrow may help to clarify this situation.

Jennings et al., (1974) demonstrated a shortened erythrocyte survival time in rodents with T. brucei infections. Erythrokinetic studies in T. congolense infected calves showed an excessive loss of $^{51}$Cr-labelled erythrocytes from the circulation indicating a reduction in erythrocyte survival time (Holmes and Mamo, 1975).

Ferrokinetic studies by these workers provided no evidence that dyshaematopoiesis played any part in the aetiology of the anaemia.

An early onset of anaemia in trypanosomiasis has been demonstrated in laboratory animals (Boycott and Jones-Price, 1913; Jennings et al., 1974; Murray et al., 1974) and in cattle (Fiennes, 1954; Naylor, 1971b; Losos et al., 1973; Wellde et al., 1974; Murray, 1974). Jennings et al., (1974) suggested that the early onset of anaemia in rats and mice with T. brucei infections was not of immune origin. The possibility of damage to the erythrocytes as a direct result of trypanosome infection

was suggested. Early onset of anaemia was observed in all infected cows. Fiennes (1954) postulated that the anaemia that developed in this phase of disease resulted from haemodilution. Naylor (1971b) observed increased plasma volume during this phase of disease. Holmes and Mamo (1975) observed that as the anaemia developed, there was an absolute fall in the circulating erythrocytes mass and an over-compensatory increase in plasma volume. They concluded that haemodilution was of secondary importance in bringing about the anaemia. Hawkins et al., (1975) suggested that the early anaemia in T. congolense infected calves was due to a direct toxic action of the trypanosomes upon the blood, and that in the initial phase it was not due to immune processes or to a depression of erythropoiesis. There is no concensus of opinion on the mechanisms responsible for the early onset of anaemia in trypanosomiasis. It is unlikely that this early anaemia results from host response to the trypanosomes but rather from the effect of trypanosomes in the host. Additional studies are required to establish the role of haemodilution and trypanosome toxins in the development of anaemia in the early stages of trypanosomiasis.

There is considerable evidence that in certain phases of trypanosomiasis, the anaemia is a consequence of

accelerated erythrocyte destruction. Boycott and Jones-Price (1913) observed that erythrophagocytosis was a primary factor in development of anaemia in rabbit trypanosomiasis. Similar observations have been made in cattle (Fiennes et al., 1946; Fiennes, 1954; Naylor, 1971c; Losos, et al., 1973; Wellde, et al., 1974) and in sheep and goats (Edwards et al., 1956). MacKenzie and Cruickshank (1973) demonstrated intense erythrophagocytosis in sheep with T. congolense infection. They postulated that erythrophagocytosis contributed substantially to the anaemia and that it was a prime factor. The markedly increased erythropoiesis in the bone marrow, haemosiderosis and erythrophagocytosis and the absence of haemoglobinaemia and haemoglobinuria in all uncomplicated T. vivax or T. congolense infections suggested that erythrocyte destruction was extravascular. Similar conclusions have been made in sheep with T. congolense infection (MacKenzie and Cruickshank, 1973) and in rats with T. evansi infection (Assoku, 1975).

The mechanisms that account for the enhanced extravascular destruction of erythrocytes are not well established. There is some evidence that erythrocyte destruction in trypanosomiasis is immunologically mediated

(Fiennes, 1954; MacKenzie and Cruickshank, 1973; Esuruoso, 1974; Assoku, 1975) but direct demonstration of the immunologic mechanisms involved has not been achieved. The possibility of more than one operating mechanism in development of anaemia of trypanosomiasis cannot be eliminated.

Results of plasma iron studies in these cattle provided further support to the conclusion that haemolysis in trypanosomiasis occurred extravascularly as hyperferremia, haemoglobinaemia and haemoglobinuria were not demonstrated in any uncomplicated T. vivax and T. congolense infection. A summary of expected derangements in SI and TIBC in various types of anaemias is presented in table 1. Intravascular haemolysis is usually associated with increased plasma iron. The occasional increases in PI in these cattle occurred in association with babesiosis, a known cause of intravascular haemolysis in cattle. Haemoglobinuria was demonstrated in one cow with severe babesiosis as an intercurrent infection. Where intercurrent infection with Anaplasma marginale occurred, there was no apparent increase in PI and haemoglobinuria was not demonstrated.

It has been observed that in chronically infected

cattle, the anaemia becomes microcytic and spleen atrophied, indicating the possibility of iron deficiency or bone marrow failure (Fiennes, 1970). Tartour and Idris (1973) observed protracted hypoferremia in 2 calves late in infection indicating failure of release of storage iron from spleen, liver and other storage organs. Iron deficiency anaemia is usually associated with low PI, high TIBC and very low SC (less than 15%) while anaemias of bone marrow failure are associated with high PI, normal TIBC and high SC (50-90%) (Hillman, 1970). Protracted hypoferremia was not observed in these experiments. Preliminary findings on serum copper levels in cattle with T. vivax infection indicated hypocupraemia was not a feature of trypanosomiasis (Saror, 1975). Occasional increases in PI that were observed occurred in association with babesiosis and could not have resulted from bone marrow aplasia. It may be concluded that neither iron deficiency nor bone marrow aplasia are principal causes of the anaemia of bovine trypanosomiasis during the first 9 weeks of infection. Further studies on the role of other elements involved in haematopoiesis such as cobalt in the development of the anaemia are in progress.

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Table 1: Summary of derangements in serum iron and total iron-binding capacity in various types of anaemia*.

| Disease | SI | TIBC |
|---|---|---|
| Iron Deficiency | Decrease | Increase |
| Haemolytic | Increase | Decrease |
| Bone Marrow Aplasia | Increase | Normal |
| Nuclear Maturation Defects | NL→Increase | Normal |

* Adapted from Hillman, 1970 and Kaneko, 1970.

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# APPENDIX I: HAEMATOLOGIC VALUES IN ZEBU CATTLE UNDER NATIVE HUSBANDRY PRACTICES

Table 1 : Haematologic parameters of 54 Zebu calves aged from birth to 4 weeks

| Age (wks) | PCV % | Hb Gm/dl | RBC x $10^6/mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 1 | 32.0 | 10.1 | 8.50 | 12250 | 58 | 41 | 1 | 0 |
| 1 | 34.0 | 10.5 | 7.94 | 5100 | 72 | 24 | 3 | 1 |
| 1 | 38.0 | 12.2 | 9.54 | 6050 | 64 | 30 | 4 | 2 |
| 1 | 31.0 | 10.0 | 7.95 | 5050 | 60 | 36 | 1 | 3 |
| 1 | 40.0 | 13.1 | 11.26 | 5850 | 62 | 37 | 1 | 0 |
| 1 | 29.0 | 9.4 | 7.98 | 5000 | 50 | 46 | 0 | 4 |
| 1 | 38.0 | 12.5 | 11.56 | 5950 | 65 | 31 | 3 | 1 |
| 1 | 32.0 | 10.1 | 11.47 | 4150 | 78 | 19 | 0 | 3 |
| 1 | 29.0 | 9.9 | 8.15 | 4750 | 62 | 36 | 1 | 1 |
| 1 | 39.0 | 13.0 | 10.05 | 5400 | 50 | 49 | 1 | 0 |
| 1 | 27.0 | 9.0 | 5.96 | 5900 | 55 | 40 | 3 | 2 |
| 1 | 33.0 | 11.7 | 7.95 | 14700 | 47 | 53 | 0 | 0 |
| 2 | 31.0 | 10.0 | 7.64 | 11050 | 49 | 48 | 0 | 3 |
| 2 | 46.0 | 15.2 | 14.09 | 7300 | 65 | 30 | 1 | 4 |
| 2 | 43.0 | 13.8 | 13.15 | 6950 | 75 | 20 | 0 | 5 |
| 2 | 46.0 | 15.2 | 12.70 | 6050 | 72 | 24 | 1 | 3 |
| 2 | 31.0 | 10.3 | 8.30 | 7350 | 80 | 17 | 3 | 0 |
| 2 | 51.0 | 15.4 | 8.92 | 7550 | 65 | 30 | 2 | 3 |
| 2 | 30.0 | 10.0 | 9.24 | 9350 | 80 | 16 | 2 | 2 |
| 2 | 42 | 13.9 | 7.90 | 10050 | 74 | 22 | 1 | 3 |
| 2 | 28.0 | 9.5 | 7.17 | 11450 | 62 | 34 | 2 | 2 |
| 2 | 34.0 | 10.5 | 9.52 | 8500 | 80 | 16 | 1 | 3 |
| 2 | 30.0 | 10.0 | 9.00 | 7150 | 65 | 30 | 3 | 2 |
| 2 | 32.0 | 10.4 | 9.76 | 8550 | 57 | 41 | 0 | 2 |
| 2 | 34.0 | 10.7 | 9.05 | 7100 | 72 | 28 | 0 | 0 |
| 2 | 34.0 | 11.1 | 9.05 | 13000 | 88 | 11 | 1 | 0 |
| 2 | 40.0 | 13.3 | 13.05 | 12950 | 86 | 12 | 2 | 0 |

Table 1 : (Cont'd)

| Age (wks) | PCV % | Hb Gm/dl | RBC x $10^6/mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 3 | 27.0 | 8.8 | 6.19 | 7650 | 72 | 26 | 1 | 1 |
| 3 | 40.0 | 13.0 | 11.46 | 10850 | 67 | 27 | 4 | 2 |
| 3 | 38.0 | 12.4 | 10.50 | 9150 | 93 | 6 | 1 | 0 |
| 3 | 27.0 | 8.8 | 7.53 | 5750 | 54 | 42 | 1 | 3 |
| 3 | 40.0 | 13.4 | 9.42 | 3000 | 64 | 34 | 0 | 2 |
| 3 | 32.0 | 11.0 | 9.48 | 2850 | 84 | 9 | 5 | 2 |
| 3 | 37.0 | 11.2 | 9.06 | 8600 | 55 | 40 | 4 | 1 |
| 3 | 30.0 | 9.5 | 8.06 | 6100 | 81 | 17 | 2 | 0 |
| 3 | 30.0 | 9.5 | 6.82 | 7900 | 77 | 20 | 1 | 2 |
| 3 | 36.0 | 12.0 | 9.90 | 10750 | 80 | 18 | 1 | 1 |
| 3 | 43.0 | 13.1 | 8.20 | 12750 | 81 | 18 | 1 | 0 |
| 3 | 40.0 | 12.6 | 9.62 | 5150 | 70 | 28 | 0 | 2 |
| 3 | 35.0 | 11.7 | 10.35 | 11950 | 64 | 36 | 0 | 0 |
| 4 | 38.0 | 11.7 | 11.45 | 16600 | 89 | 10 | 0 | 1 |
| 4 | 35.0 | 11.5 | 11.5 | 12300 | 75 | 20 | 0 | 5 |
| 4 | 32.0 | 10.1 | 9.45 | 11500 | 81 | 17 | 1 | 1 |
| 4 | 40.0 | 13.1 | 12.00 | 6850 | 73 | 24 | 3 | 0 |
| 4 | 29.0 | 10.1 | 8.91 | 15000 | 77 | 23 | 0 | 0 |
| 4 | 34.0 | 11.4 | 8.78 | 9800 | 89 | 11 | 0 | 0 |
| 4 | 38.0 | 11.6 | 10.47 | 12150 | 79 | 19 | 2 | 0 |
| 4 | 32.0 | 10.5 | 10.03 | 7150 | 82 | 18 | 0 | 0 |
| 4 | 34.0 | 11.0 | 9.01 | 7250 | 88 | 12 | 0 | 0 |
| 4 | 35.0 | 11.5 | 9.79 | 14050 | 83 | 16 | 1 | 0 |
| 4 | 38.0 | 12.5 | 10.24 | 4000 | 77 | 20 | 2 | 0 |
| 4 | 41.0 | 13.2 | 9.92 | 6550 | 89 | 7 | 1 | 3 |
| 4 | 32.0 | 10.0 | 7.91 | 10250 | 74 | 25 | 0 | 1 |
| 4 | 31.0 | 9.6 | 6.53 | 6150 | 72 | 27 | 1 | 0 |

Table 2 : Haematologic parameters of Zebu calves aged 5 weeks to 12 months

| Age (mths) | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 1 | 27.0 | 9.2 | 7.22 | 8100 | 78 | 20 | 2 | 0 |
| 2 | 31.0 | 10.5 | 7.46 | 5650 | 80 | 18 | 1 | 1 |
| 2 | 29.0 | 9.2 | 5.60 | 6450 | 75 | 20 | 3 | 2 |
| 2 | 36.0 | 11.2 | 9.48 | 9900 | 71 | 28 | 1 | 0 |
| 2 | 41.0 | 13.5 | 10.28 | 8000 | 62 | 30 | 6 | 2 |
| 2 | 29.0 | 9.9 | 9.47 | 12950 | 70 | 26 | 1 | 3 |
| 3 | 30.0 | 9.9 | 8.19 | 9650 | 65 | 30 | 4 | 1 |
| 3 | 36.0 | 11.2 | 8.19 | 9100 | 56 | 40 | 1 | 3 |
| 3 | 28.0 | 8.6 | 6.60 | 14350 | 72 | 24 | 2 | 2 |
| 3 | 30.0 | 10.2 | 8.66 | 9050 | 80 | 16 | 2 | 2 |
| 3 | 40.0 | 13.0 | 12.15 | 4550 | 80 | 15 | 4 | 1 |
| 3 | 30.0 | 10.2 | 8.29 | 6200 | 80 | 19 | 0 | 1 |
| 3 | 36.0 | 11.6 | 8.05 | 11000 | 95 | 5 | 0 | 0 |
| 3 | 34.0 | 11.5 | 7.20 | 7050 | 81 | 9 | 10 | 0 |
| 3 | 35.0 | 11.4 | 10.21 | 9100 | 80 | 19 | 1 | 0 |
| 3 | 37.0 | 12.7 | 9.97 | 23250 | 61 | 39 | 0 | 0 |
| 3 | 43.0 | 14.6 | 10.96 | 12900 | 82 | 16 | 2 | 0 |
| 3 | 37.0 | 12.5 | 10.48 | 9750 | 68 | 31 | 1 | 0 |
| 3 | 37.0 | 12.5 | 8.22 | 12400 | 75 | 23 | 2 | 0 |
| 3 | 33.0 | 11.1 | 13.41 | 16600 | 77 | 18 | 4 | 1 |
| 3 | 33.0 | 10.7 | 9.81 | 7100 | 73 | 19 | 8 | 0 |
| 3 | 33.0 | 11.0 | 10.58 | 9450 | 66 | 31 | 0 | 3 |
| 3 | 28.0 | 9.7 | 10.39 | 9700 | 78 | 14 | 2 | 6 |
| 3 | 32.0 | 10.4 | 11.16 | 8050 | 51 | 38 | 8 | 3 |
| 3 | 32.0 | 10.4 | 11.10 | 7850 | 92 | 8 | 0 | 0 |
| 3 | 34.0 | 11.3 | 12.80 | 8800 | 76 | 21 | 3 | 0 |
| 3 | 35.0 | 11.7 | 10.35 | 11950 | 04 | 36 | 0 | 0 |
| 4 | 30.0 | 9.6 | 5.53 | 5900 | 88 | 9 | 2 | 1 |
| 4 | 25.0 | 8.0 | 5.38 | 7000 | 78 | 12 | 7 | 3 |

Table 2 : (Cont'd)

| Age (mths) | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 4 | 31.0 | 10.8 | 8.05 | 6650 | 85 | 12 | 2 | 1 |
| 4 | 30.0 | 9.9 | 7.60 | 5350 | 75 | 17 | 7 | 1 |
| 4 | 31.0 | 10.7 | 8.78 | 11750 | 72 | 22 | 6 | 0 |
| 4 | 41.0 | 13.8 | 10.11 | 14400 | 71 | 24 | 5 | 0 |
| 4 | 35.0 | 11.1 | 9.25 | 10050 | 83 | 14 | 3 | 0 |
| 5 | 33.0 | 11.0 | 6.94 | 10450 | 61 | 26 | 9 | 4 |
| 5 | 37.0 | 12.1 | 8.66 | 11350 | 55 | 36 | 1 | 8 |
| 5 | 36.0 | 12.4 | 9.61 | 12350 | 77 | 20 | 3 | 0 |
| 5 | 39.0 | 13.3 | 10.92 | 14450 | 60 | 37 | 3 | 0 |
| 5 | 30.0 | 9.7 | 9.11 | 12150 | 81 | 17 | 0 | 2 |
| 5 | 35.0 | 11.8 | 12.74 | 10550 | 67 | 31 | 1 | 1 |
| 6 | 25.0 | 8.1 | 7.78 | 5500 | 61 | 34 | 3 | 2 |
| 6 | 26.0 | 8.6 | 7.06 | 8150 | 83 | 16 | 1 | 0 |
| 6 | 31.0 | 10.5 | 7.94 | 8600 | 72 | 25 | 2 | 1 |
| 6 | 35.0 | 12.0 | 10.64 | 9850 | 53 | 31 | 15 | 1 |
| 7 | 30.0 | 10.5 | 7.10 | 15350 | 65 | 23 | 11 | 1 |
| 7 | 35.0 | 12.2 | 6.55 | 8950 | 61 | 29 | 7 | 3 |
| 8 | 27.0 | 8.9 | 6.62 | 5650 | 67 | 28 | 3 | 2 |
| 8 | 29.0 | 9.5 | 6.87 | 10250 | 72 | 9 | 17 | 2 |
| 8 | 36.0 | 12.0 | 10.00 | 6450 | 73 | 21 | 4 | 2 |
| 8 | 40.0 | 13.4 | 10.12 | 9550 | 78 | 17 | 2 | 3 |
| 8 | 33.0 | 11.4 | 7.08 | 9400 | 65 | 29 | 3 | 3 |
| 8 | 36.0 | 12.4 | 6.79 | 8900 | 64 | 25 | 7 | 4 |
| 8 | 34.0 | 11.8 | 7.90 | 7250 | 84 | 8 | 5 | 3 |

Table 2 : (Cont'd)

| Age (mths) | PCV % | Hb Gm/dl | REC x $10^6/mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 8 | 37.0 | 12.2 | 9.43 | 12000 | 66 | 27 | 4 | 3 |
| 9 | 29.0 | 9.9 | 10.44 | 9450 | 80 | 12 | 7 | 1 |
| 12 | 31.0 | 11.0 | 7.72 | 15550 | 92 | 2 | 3 | 3 |
| 12 | 25.0 | 8.2 | 4.54 | 3600 | 57 | 31 | 12 | 0 |
| 12 | 27.0 | 9.6 | 6.93 | 7850 | 71 | 21 | 7 | 1 |
| 12 | 30.0 | 10.2 | 9.71 | 14250 | 90 | 7 | 3 | 1 |
| 12 | 30.0 | 10.0 | 7.48 | 8050 | 77 | 18 | 4 | 1 |
| 12 | 26.0 | 8.5 | 6.68 | 9550 | 76 | 20 | 4 | 0 |
| 12 | 26.0 | 9.2 | 7.08 | 7350 | 76 | 21 | 1 | 2 |
| 12 | 31.0 | 11.0 | 8.89 | 11250 | 75 | 19 | 6 | 0 |
| 12 | 33.0 | 11.7 | 8.80 | 21400 | 95 | 3 | 1 | 0 |
| 12 | 31.0 | 10.7 | 7.46 | 9350 | 68 | 22 | 9 | 1 |
| 12 | 25.0 | 8.3 | 6.34 | 13500 | 68 | 19 | 12 | 0 |
| 12 | 33.0 | 11.5 | 8.08 | 10700 | 71 | 14 | 14 | 1 |
| 12 | 33.0 | 11.5 | 6.55 | 9650 | 88 | 10 | 0 | 2 |
| 12 | 37.0 | 13.0 | 9.45 | 21400 | 86 | 8 | 8 | 0 |

Table 3 : Haematologic parameters of 44 Zebu cattle aged 1 to 3 years

| Age (yrs) | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 1.0 | 27.0 | 8.3 | 7.35 | 13800 | 65 | 30 | 5 | 0 |
| 1.0 | 26.0 | 8.4 | 6.32 | 18550 | 72 | 21 | 7 | 0 |
| 1.5 | 33.0 | 11.0 | 7.78 | 17250 | 61 | 29 | 10 | 0 |
| 1.5 | 26.0 | 8.0 | 6.27 | 15350 | 81 | 14 | 5 | 0 |
| 1.5 | 26.0 | 9.0 | 7.29 | 13600 | 78 | 15 | 5 | 2 |
| 1.5 | 27.0 | 8.7 | 6.97 | 16850 | 64 | 29 | 5 | 2 |
| 1.5 | 28.0 | 8.7 | 8.28 | 16650 | 67 | 28 | 5 | 0 |
| 1.5 | 30.0 | 9.3 | 7.28 | 25200 | 66 | 22 | 11 | 1 |
| 1.5 | 29.0 | 8.7 | 7.64 | 17125 | 75 | 14 | 11 | 0 |
| 1.5 | 28.0 | 9.3 | 7.76 | 12150 | 65 | 21 | 12 | 2 |
| 1.5 | 32.0 | 10.0 | 8.00 | 20150 | 73 | 19 | 88 | 0 |
| 1.5 | 31.0 | 9.7 | 9.32 | 16150 | 64 | 31 | 4 | 0 |
| 1.5 | 28.0 | 8.7 | 7.60 | 10100 | 62 | 23 | 15 | 0 |
| 1.5 | 28.0 | 9.3 | 7.15 | 10700 | 88 | 10 | 2 | 0 |
| 1.5 | 30.0 | 9.7 | 8.68 | 15300 | 83 | 16 | 1 | 0 |
| 1.5 | 29.0 | 9.0 | 8.08 | 11150 | 73 | 23 | 41 | 0 |
| 1.5 | 28.0 | 8.7 | 7.68 | 9000 | 70 | 22 | 7 | 1 |
| 1.5 | 26.0 | 8.4 | 6.85 | 9500 | 78 | 12 | 7 | 3 |
| 1.5 | 29.0 | 9.0 | 8.43 | 10450 | 58 | 26 | 5 | 1 |
| 1.5 | 27.0 | 8.4 | 6.91 | 19550 | 66 | 22 | 10 | 2 |
| 1.5 | 34.0 | 10.7 | 9.59 | 13050 | 62 | 31 | 5 | 2 |
| 1.5 | 26.0 | 8.7 | 7.99 | 12850 | 77 | 19 | 4 | 0 |
| 1.5 | 27.0 | 7.4 | 6.75 | 15150 | 84 | 12 | 1 | 3 |
| 1.5 | 28.0 | 8.4 | 8.00 | 11800 | 66 | 28 | 5 | 1 |
| 2.0 | 28.0 | 9.3 | 6.70 | 8750 | 61 | 21 | 16 | 2 |
| 2.0 | 26.0 | 8.7 | 6.87 | 13650 | 69 | 26 | 5 | 0 |
| 2.0 | 30.0 | 9.3 | 5.41 | 16750 | 65 | 28 | 7 | 0 |
| 2.0 | 29.0 | 8.4 | 6.20 | 16350 | 69 | 23 | 8 | 0 |

Table 3 : (Cont'd)

| Age (yrs) | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| 2.0 | 34.0 | 11.0 | 5.09 | 13750 | 75 | 21 | 1 | 3 |
| 2.0 | 27.0 | 9.3 | 7.12 | 14250 | 76 | 22 | 2 | 0 |
| 2.0 | 31.0 | 10.0 | 7.95 | 24750 | 71 | 24 | 5 | 0 |
| 2.0 | 26.0 | 8.0 | 7.00 | 14650 | 71 | 22 | 1 | 6 |
| 2.0 | 32.0 | 10.0 | 8.43 | 10350 | 69 | 23 | 6 | 2 |
| 2.0 | 27.0 | 8.4 | 8.09 | 11750 | 70 | 25 | 5 | 0 |
| 2.0 | 34.0 | 11.3 | 8.07 | 10800 | 71 | 27 | 2 | 0 |
| 2.0 | 32.0 | 9.7 | 8.27 | 11850 | 72 | 18 | 9 | 1 |
| 2.0 | 27.0 | 9.0 | 7.91 | 14850 | 80 | 20 | 0 | 0 |
| 2.0 | 27.0 | 8.4 | 7.62 | 10850 | 74 | 19 | 7 | 0 |
| 2.0 | 26.0 | 8.7 | 6.81 | 14950 | 47 | 48 | 1 | 4 |
| 2.0 | 27.0 | 8.7 | 8.78 | 14400 | 66 | 28 | 5 | 1 |
| 2.5 | 28.0 | 9.3 | 6.59 | 13850 | 69 | 22 | 7 | 2 |
| 2.5 | 30.0 | 10.3 | 9.35 | 16550 | 66 | 27 | 6 | 1 |
| 2.5 | 25.0 | 7.4 | 5.82 | 10150 | 74 | 19 | 5 | 2 |

# APPENDIX 2 : DAILY VARIATIONS IN SI, UIBC, TIBC AND SC IN ADULT ZEBU CATTLE

Table 1 : Daily SI, UIBC, TIBC and SC values in cow No. 1

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 185 | 250 | 435 | 42.5 |
| 2 | 155 | 200 | 355 | 43.7 |
| 3 | 185 | 235 | 420 | 44.0 |
| 4 | 150 | 200 | 350 | 42.9 |
| 5 | 175 | 185 | 360 | 48.6 |
| 6 | 175 | 225 | 400 | 43.7 |
| 7 | 170 | 210 | 380 | 44.8 |
| 8 | 168 | 250 | 418 | 40.3 |
| 9 | 160 | 250 | 410 | 39.0 |
| 10 | 165 | 245 | 410 | 40.2 |

Table 2 : Daily SI, UIBC, TIBC and SC values in cow No. 2

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 174 | 155 | 329 | 52.9 |
| 2 | 195 | 185 | 380 | 51.4 |
| 3 | 200 | 180 | 380 | 52.6 |
| 4 | 200 | 185 | 385 | 52.0 |
| 5 | 155 | 200 | 355 | 43.6 |
| 6 | 160 | 225 | 385 | 41.5 |
| 7 | 160 | 230 | 390 | 41.0 |
| 8 | 195 | 230 | 425 | 45.8 |
| 9 | 150 | 210 | 360 | 41.7 |
| 10 | 180 | 200 | 380 | 47.4 |

Table3 : Daily SI, UIBC, TIBC and SC values in cow No. 3

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 125 | 240 | 365 | 34.2 |
| 2 | 140 | 210 | 350 | 40.0 |
| 3 | 160 | 190 | 350 | 45.7 |
| 4 | 180 | 160 | 340 | 53.0 |
| 5 | 154 | 180 | 334 | 46.1 |
| 6 | 148 | 210 | 358 | 41.4 |
| 7 | 170 | 170 | 340 | 50.0 |
| 8 | 145 | 215 | 355 | 40.8 |
| 9 | 150 | 230 | 380 | 39.7 |
| 10 | 150 | 200 | 350 | 42.9 |

Table 4 : Daily SI, UIBC, TIBC and SC values in cow No. 4

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 140 | 250 | 390 | 35.9 |
| 2 | 135 | 230 | 365 | 37.0 |
| 3 | 155 | 195 | 350 | 44.4 |
| 4 | 130 | 200 | 330 | 39.4 |
| 5 | 140 | 185 | 325 | 43.0 |
| 6 | 140 | 200 | 340 | 41.2 |
| 7 | 140 | 190 | 330 | 42.4 |
| 8 | 150 | 212 | 362 | 41.5 |
| 9 | 132 | 220 | 352 | 37.5 |
| 10 | 130 | 235 | 365 | 35.6 |

Table 5 : Daily SI, UIBC, TIBC and SC values in cow No. 5

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 132 | 240 | 372 | 35.4 |
| 2 | 120 | 230 | 350 | 34.2 |
| 3 | 125 | 200 | 325 | 38.5 |
| 4 | 115 | 240 | 355 | 32.4 |
| 5 | 132 | 245 | 377 | 35.0 |
| 6 | 115 | 210 | 325 | 35.4 |
| 7 | 125 | 210 | 335 | 37.3 |
| 8 | 125 | 200 | 325 | 38.5 |
| 9 | 105 | 200 | 305 | 34.4 |
| 10 | 115 | 235 | 350 | 32.8 |

Table 6 : Daily SI, UIBC, TIBC and SC values in cow No. 6

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 130 | 190 | 320 | 40.6 |
| 2 | 85 | 230 | 315 | 27.0 |
| 3 | 105 | 225 | 330 | 31.8 |
| 4 | 95 | 185 | 280 | 33.9 |
| 5 | 70 | 205 | 275 | 25.4 |
| 6 | 85 | 225 | 310 | 27.4 |
| 7 | 108 | 200 | 308 | 35.0 |
| 8 | 130 | 230 | 360 | 36.1 |
| 9 | 90 | 205 | 295 | 30.5 |
| 10 | 90 | 230 | 320 | 28.1 |

Table 7 : Daily SI, UIBC, TIBC and SC values in cow No. 7

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 100 | 255 | 355 | 28.2 |
| 2 | 105 | 260 | 365 | 28.8 |
| 3 | 90 | 235 | 325 | 27.7 |
| 4 | 85 | 240 | 325 | 26.1 |
| 5 | 118 | 184 | 302 | 39.0 |
| 6 | 105 | 190 | 295 | 35.6 |
| 7 | 106 | 195 | 301 | 35.2 |
| 8 | 110 | 145 | 255 | 43.1 |
| 9 | 105 | 200 | 305 | 34.4 |
| 10 | 106 | 195 | 301 | 35.2 |

Table 8 : Daily SI,UIBC, TIBC and SC values in cow No. 8

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 70 | 205 | 275 | 25.4 |
| 2 | 75 | 180 | 255 | 29.4 |
| 3 | 50 | 265 | 315 | 15.9 |
| 4 | 60 | 225 | 285 | 21.0 |
| 5 | 95 | 155 | 250 | 38.0 |
| 6 | 65 | 195 | 260 | 25.0 |
| 7 | 72 | 200 | 272 | 26.5 |
| 8 | 95 | 180 | 275 | 34.6 |
| 9 | 75 | 160 | 235 | 32.0 |
| 10 | 80 | 160 | 240 | 33.4 |

Table 9 : Daily SI, UIBC, TIBC and SC values in cow No. 9

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 110 | 225 | 335 | 32.8 |
| 2 | 145 | 190 | 335 | 43.3 |
| 3 | 170 | 225 | 395 | 43.0 |
| 4 | 160 | 225 | 385 | 41.6 |
| 5 | 115 | 190 | 305 | 37.7 |
| 6 | 155 | 160 | 315 | 49.2 |
| 7 | 165 | 145 | 310 | 53.2 |
| 8 | 150 | 180 | 330 | 45.4 |
| 9 | 160 | 180 | 340 | 47.0 |
| 10 | 180 | 200 | 380 | 47.4 |

Table 10: Daily SI, UIBC, TIBC and SC values in cow No.10

| Days of Observation | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 132 | 175 | 307 | 43.0 |
| 2 | 125 | 220 | 345 | 36.2 |
| 3 | 110 | 145 | 255 | 43.0 |
| 4 | 130 | 185 | 315 | 41.3 |
| 5 | 115 | 95 | 210 | 54.8 |
| 6 | 120 | 130 | 250 | 48.0 |
| 7 | 125 | 180 | 305 | 41.0 |
| 8 | 130 | 195 | 325 | 40.0 |
| 9 | 115 | 100 | 215 | 53.5 |
| 10 | 125 | 160 | 285 | 43.8 |

# APPENDIX 3 : VARIATIONS WITH AGE IN SI, UIBC, TIBC, AND SC OF ZEBU CATTLE

Table 1: SI. UIBC, TIBC and SC of clinically healthy calves from birth to 4 weeks.

| Age (weeks) | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 92.5 | 180.0 | 272.5 | 33.9 |
| 1 | 68.0 | 260.0 | 328.0 | 20.7 |
| 1 | 85.0 | 240.0 | 325.0 | 26.2 |
| 1 | 100.0 | 170.0 | 270.0 | 37.0 |
| 1 | 145.0 | 200.0 | 345.0 | 42.0 |
| 2 | 90.0 | 200.0 | 290.0 | 31.0 |
| 2 | 59.0 | 190.0 | 246.0 | 22.8 |
| 2 | 68.0 | 170.0 | 238.0 | 28.6 |
| 2 | 135.0 | 180.0 | 315.0 | 42.9 |
| 2 | 112.5 | 117.5 | 230.0 | 48.9 |
| 2 | 112.5 | 117.5 | 230.0 | 48.9 |
| 2 | 152.0 | 157.5 | 309.5 | 49.1 |
| 3 | 62.5 | 230.0 | 292.5 | 21.4 |
| 3 | 117.5 | 157.5 | 275.0 | 42.7 |
| 3 | 100.0 | 107.5 | 207.5 | 48.2 |
| 3 | 90.0 | 210.0 | 300.0 | 30.0 |
| 3 | 45.0 | 107.5 | 152.5 | 29.5 |
| 3 | 76.0 | 200.0 | 276.0 | 27.5 |
| 3 | 180.0 | 200.0 | 380.0 | 47.4 |
| 3 | 137.5 | 190.0 | 327.5 | 41.9 |
| 4 | 112.5 | 117.5 | 230.0 | 48.9 |
| 4 | 56.0 | 200.0 | 256.0 | 29.7 |
| 4 | 92.5 | 117.5 | 210.0 | 44.1 |
| 4 | 56.0 | 230.0 | 286.0 | 19.6 |
| 4 | 135.0 | 270.0 | 405.0 | 33.3 |
| 4 | 135.0 | 180.0 | 315.0 | 42.9 |
| 4 | 122.5 | 250.0 | 372.5 | 32.9 |
| 4 | 180.0 | 140.0 | 320.0 | 56.3 |

Table 1 :(Cont'd)



| Age (weeks) | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 4 | 190.0 | 200.0 | 390.0 | 48.7 |
| 4 | 150.0 | 117.5 | 267.5 | 56.1 |
| 4 | 152.0 | 260.0 | 412.0 | 36.9 |
| 4 | 100.0 | 300.0 | 400.0 | 25.0 |
| 4 | 152.0 | 240.0 | 392.0 | 38.8 |
| 4 | 92.5 | 306.0 | 398.5 | 23.2 |

Table 2 : SI, UIBC, T BC and SC in calves, 5 weeks to 1 year of age.

| Age (Months) | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 135.0 | 220.0 | 355.0 | 38.0 |
| 1 | 117.5 | 80.0 | 197.5 | 59.5 |
| 1 | 122.5 | 117.5 | 240.0 | 51.0 |
| 1 | 170.0 | 80.0 | 250.0 | 68.0 |
| 2 | 90.0 | 117.5 | 207.5 | 43.4 |
| 2 | 100.0 | 260.0 | 260.0 | 27.6 |
| 2 | 68.0 | 220.0 | 288.0 | 23.6 |
| 3 | 72.5 | 150.0 | 222.5 | 32.6 |
| 3 | 76.0 | 180.0 | 256.0 | 29.7 |
| 3 | 145.0 | 80.0 | 225.0 | 64.5 |
| 3 | 72.5 | 100.5 | 172.5 | 42.0 |
| 3 | 76.0 | 260.0 | 336.0 | 22.6 |
| 3 | 137.5 | 200.0 | 337.5 | 40.7 |
| 3 | 135.0 | 100.0 | 235.0 | 57.5 |
| 3 | 172.5 | 100.0 | 372.5 | 46.3 |
| 3 | 137.5 | 190.0 | 327.5 | 42.0 |
| 3 | 117.5 | 240.0 | 352.5 | 32.9 |
| 3 | 200.0 | 260.0 | 460.0 | 43.5 |
| 3 | 200.0 | 320.0 | 520.0 | 38.5 |
| 3 | 145.0 | 220.0 | 365.0 | 39.7 |
| 3 | 145.0 | 230.0 | 375.0 | 38.7 |
| $3\frac{1}{2}$ | 185.0 | 100.0 | 285.0 | 64.9 |
| $3\frac{1}{2}$ | 180.0 | 190.0 | 370.0 | 48.7 |
| 4 | 102.0 | 190.0 | 392.0 | 51.4 |
| 4 | 180.0 | 200.0 | 380.0 | 47.4 |
| 4 | 122.5 | 320.0 | 442.05 | 27.7 |
| 4 | 255.0 | 127.5 | 382.5 | 66.7 |
| $4\frac{1}{2}$ | 110.0 | 107.5 | 277.5 | 61.3 |

Table 2 : (Cont'd)

| Age (months) | SI ug/dl | UIPC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 5 | 137.5 | 210.0 | 347.5 | 39.5 |
| 5 | 150.0 | 240.0 | 390.0 | 38.5 |
| 5 | 172.5 | 170.0 | 342.5 | 50.4 |
| 5 | 275.0 | 190.0 | 465.0 | 59.1 |
| 6 | 112.5 | 200.0 | 312.5 | 36.0 |
| 8 | 100.0 | 230.0 | 330.0 | 30.3 |
| 9 | 162.5 | 170.0 | 332.5 | 48.9 |
| 9 | 137.5 | 260.0 | 397.5 | 34.6 |

Table 3: SI, UIBC, TIBC and SC of heifers 1 to 3 years old.

| Age (years) | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1.0 | 137.5 | 80 | 217.5 | 63.2 |
| 1.0 | 90 | 200 | 290 | 31.0 |
| 1.0 | 106.5 | 117.5 | 224 | 90.6 |
| 1.5 | 225 | 117.5 | 342.5 | 65.7 |
| 1.5 | 127.5 | 200 | 327.5 | 38.9 |
| 1.5 | 150 | 140 | 290 | 51.7 |
| 1.5 | 137.5 | 94 | 231.5 | 59.4 |
| 1.5 | 127.5 | 190 | 317.5 | 40.2 |
| 1.5 | 92.5 | 127.5 | 220 | 42.1 |
| 1.5 | 127.5 | 210 | 337.5 | 37.8 |
| 1.5 | 162.5 | 140 | 302.5 | 53.7 |
| 1.5 | 162.5 | 150 | 312.5 | 52.0 |
| 1.5 | 180 | 100 | 280 | 64.3 |
| 1.5 | 106.5 | 127.5 | 234 | 45.5 |
| 1.5 | 202 | 127.5 | 329.5 | 61.3 |
| 1.5 | 162.5 | 117.5 | 280 | 58.1 |
| 1.5 | 145 | 127.5 | 272.5 | 53.2 |
| 1.5 | 102.5 | 180 | 342.5 | 47.5 |
| 1.5 | 172.5 | 157.5 | 330 | 52.3 |
| 1.5 | 117.5 | 157.5 | 275 | 42.7 |
| 1.5 | 122.5 | 117.5 | 240 | 51.0 |
| 2.0 | 180 | 107.5 | 287.5 | 62.6 |
| 2.0 | 92.5 | 180 | 272.5 | 33.9 |
| 2.0 | 170 | 100 | 270 | 63.0 |
| 2.0 | 122.5 | 150 | 272.5 | 45.0 |
| 2.0 | 150 | 157.5 | 307.5 | 48.8 |
| 2.0 | 135 | 140 | 275 | 49.1 |
| 2.0 | 72.5 | 150 | 222.5 | 32.6 |

Table 3: (Cont'd)

| Age (years) | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 2.0 | 170 | 127.5 | 297.5 | 57.1 |
| 2.0 | 112.5 | 190 | 320.5 | 37.2 |
| 2.0 | 127.5 | 230 | 357.5 | 35.7 |
| 2.0 | 185 | 94 | 279 | 77.3 |
| 2.0 | 145 | 180 | 325 | 44.6 |
| 2.0 | 122.5 | 157.5 | 280 | 43.8 |
| 2.0 | 160 | 140 | 300 | 53.3 |
| 2.0 | 135 | 210 | 345 | 39.1 |
| 2.5 | 92.5 | 140 | 232.5 | 39.8 |
| 2.5 | 190 | 117.5 | 307.5 | 61.8 |
| 2.5 | 162.5 | 190 | 352.5 | 36.1 |
| 2.5 | 170 | 180 | 350 | 48.6 |
| 3.0 | 117.5 | 140 | 257.5 | 45.6 |
| 3.0 | 100 | 150 | 250 | 40.0 |

Table 4: SI, UIBC, TIBC and SC in adult Zebu cattle.

| Animal No. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| 1 | 122,5 | 117.5 | 240.0 | 51.0 |
| 2 | 155.0 | 80.0 | 235.0 | 65.9 |
| 3 | 117.5 | 57.5 | 175.0 | 67.1 |
| 4 | 145.0 | 100.0 | 245.0 | 59.2 |
| 5 | 135.0 | 100.0 | 235.0 | 57.4 |
| 6 | 200.0 | 44.0 | 244.0 | 82.0 |
| 7 | 170.0 | 127.5 | 297.5 | 57.1 |
| 8 | 155.0 | 44.0 | 199.0 | 77.9 |
| 9 | 145.0 | 67.5 | 212.5 | 68.2 |
| 10 | 122.5 | 127.5 | 250.0 | 49.0 |
| 11 | 122.5 | 100.0 | 222.5 | 55.1 |
| 12 | 117.5 | 80.0 | 197.5 | 59.5 |
| 13 | 112,5 | 200.0 | 312.5 | 36.0 |
| 14 | 127.5 | 44.0 | 171.5 | 74.3 |
| 15 | 112.5 | 100.0 | 212.5 | 52.9 |
| 16 | 137.5 | 157.5 | 295.0 | 46.6 |
| 17 | 190.0 | 170.0 | 360.0 | 52.8 |
| 18 | 106.5 | 140,0 | 246.5 | 43.2 |
| 19 | 170.0 | 80.0 | 250.0 | 68.0 |
| 20 | 112.5 | 180.0 | 292.5 | 38.5 |
| 21 | 180.0 | 150.0 | 330.0 | 54.5 |
| 22 | 92.5 | 127.5 | 220.0 | 42.0 |
| 23 | 112.5 | 140.0 | 252.5 | 44.6 |
| 24 | 90.0 | 100.0 | 190.0 | 47.4 |
| 25 | 85.0 | 210.0 | 295.0 | 28.8 |
| 26 | 90.0 | 157.5 | 247.5 | 36.4 |
| 27 | 122.5 | 127.5 | 250.0 | 49.0 |
| 28 | 117.5 | 100.0 | 217.5 | 54.0 |

# APPENDIX 4: HAEMATOLOGY, SI, UIBC, TIBC AND SC IN ZEBU CATTLE WITH *T. VIVAX* INFECTION

Table 1: Haematologic parameters and rectal temperatures in cow No. 12 experimentally infected with T. vivax.

| Days of Expt. | RBC x $10^6$/ $mm^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6.22 | 15200 | 11.8 | 35 | 74 | 20 | 2 | 4 | 38.8 |
| 0 | 6.66 | 16150 | 12.5 | 35 | 90 | 9 | 0 | I | 38.6 |
| 2 | 6.23 | 14200 | 10.9 | 33 | 87 | 13 | 0 | 0 | 38.4 |
| 4 | .8.24 | 13050 | 12.2 | 37 | 75 | 23 | 0 | 2 | 38.7 |
| 5 | 5.29 | 9000 | 9.0 | 26 | 78 | 21 | 1 | 0 | 39.8 |
| 6 | 6.29 | 10000 | 9.4 | 27 | 74 | 25 | 0 | 1 | 39.6 |
| 7 | 5.76 | 11800 | 8.2 | 25 | 81 | 19 | 0 | 0 | 39.4 |
| 8 | 5.05 | 12250 | 8.2 | 24 | 84 | 13 | 0 | 3 | 39.6 |
| 9 | 6.36 | 12400 | 8.4 | 25 | 74 | 26 | 0 | 0 | 38.3 |
| 10 | 5.99 | 10800 | 8.0 | 25 | 87 | 13 | 0 | 0 | 38.8 |
| 11 | 5.95 | 11900 | 8.5 | 25 | 86 | 14 | 0 | 0 | 38.9 |
| 12 | 5.38 | 14300 | 9.1 | 27 | 80 | 15 | 1 | 4 | 38.9 |
| 14 | 5.97 | 13750 | 8.7 | 26 | 82 | 18 | 0 | 0 | 39.2 |
| 16 | 5.43 | 10750 | 9.0 | 25 | 81 | 16 | 0 | 3 | 39.2 |
| 19 | 5.92 | 8650 | 8.0 | 23 | 76 | 23 | 0 | 1 | 40.1 |
| 21 | 5.95 | 8950 | 8.0 | 23 | 91 | 9 | 0 | 0 | 39.8 |
| 23 | 6.18 | 16100 | 9.0 | 27 | 85 | 12 | 2 | 1 | 39.6 |
| 26 | 5.88 | 11800 | 9.0 | 25 | 93 | 6 | 0 | 1 | 39.3 |
| 28 | 4.87 | 9200 | 8.3 | 24 | 82 | 18 | 0 | 0 | 39.2 |
| 30 | 5.02 | 12050 | 8.0 | 24 | 92 | 5 | 1 | 2 | 39.3 |
| 33 | 5.31 | 11500 | 7.6 | 23 | 78 | 21 | 0 | 1 | 39.8 |
| 37 | 5.06 | 11100 | 9.9 | 29 | 85 | 10 | 0 | 5 | 39.3 |
| 40 | 5.99 | 13400 | 8.0 | 26 | 90 | 10 | 0 | 0 | 39.1 |
| 47 | 6.37 | 17000 | 9.2 | 28 | 94 | 3 | 1 | 2 | 39.4 |
| 54 | 5.97 | 16250 | 9.9 | 29 | 80 | 19 | 0 | 1 | 39.1 |

Table 2 : Haematologic parameters and rectal temperatures in cow No. 13 experimentally infected with T. vivax.

| Days of Expt. | RBC x $10^6/mm^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut. % | Eo % | Mono | Temp. $^oC$ |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6.07 | 6250 | 10.1 | 30 | 72 | 23 | 5 | 0 | 38.7 |
| 0 | 5.60 | 8100 | 9.1 | 28 | 80 | 20 | 0 | 0 | 38.6 |
| 2 | 6.66 | 14000 | 9.8 | 31 | 75 | 23 | 2 | 0 | 38.8 |
| 4 | 6.25 | 12000 | 9.2 | 27 | 29 | 71 | 0 | 0 | 40.0 |
| 5 | 4.96 | 12500 | 8.2 | 24 | 24 | 76 | 0 | 0 | 40.3 |
| 6 | 4.48 | 10200 | 7.8 | 23 | 43 | 56 | 0 | 1 | 40.0 |
| 7 | 3.87 | 8950 | 7.2 | 22 | 57 | 43 | 0 | 0 | 39.8 |
| 8 | 4.29 | 7700 | 6.8 | 20 | 55 | 45 | 0 | 0 | 40.4 |
| 9 | 4.74 | 7500 | 7.2 | 21 | 74 | 25 | 0 | 1 | 39.0 |
| 10 | 4.29 | 10100 | 7.2 | 21 | 74 | 26 | 0 | 0 | 39.3 |
| 11 | 4.91 | 11050 | 7.0 | 21 | 66 | 34 | 0 | 0 | 38.9 |
| 12 | 4.40 | 12100 | 7.2 | 23 | 64 | 35 | 0 | 1 | 39.1 |
| 14 | 5.55 | 14350 | 8.0 | 22 | 72 | 28 | 0 | 0 | 39.7 |
| 16 | 4.00 | 14150 | 7.3 | 22 | 57 | 43 | 0 | 0 | 39.7 |
| 19 | 4.75 | 15150 | 7.7 | 20 | 60 | 37 | 0 | 3 | 39.9 |
| 21 | 4.61 | 13550 | 7.0 | 20 | 73 | 26 | 1 | 0 | 40.1 |
| 23 | 3.76 | 12650 | 6.5 | 19 | 65 | 33 | 1 | 1 | 39.9 |
| 26 | 3.39 | 8250 | 6.0 | 17 | 75 | 20 | 3 | 2 | 40.0 |
| 28 | 4.25 | 12050 | 7.2 | 20 | 82 | 18 | 0 | 0 | 40.4 |
| 30 | 4.53 | 8200 | 7.4 | 21 | 69 | 30 | 1 | 0 | 39.3 |
| 33 | 3.88 | 14150 | 7.1 | 21 | 52 | 48 | 0 | 0 | 40.6 |
| 37 | 3.15 | 11700 | 6.5 | 19 | 80 | 20 | 0 | 0 | 40.3 |
| 40 | 4.38 | 15300 | 6.6 | 21 | 71 | 29 | 0 | 0 | 40.0 |
| 47 | 4.19 | 16200 | 7.3 | 21 | 87 | 12 | 1 | 0 | 38.9 |
| 54 | 4.24 | 17600 | 7.1 | 20 | 62 | 36 | 0 | 2 | 38.1 |

Table 3 : Haematologic parameters and rectal temperatures in cow No. 14 experimentally infected with *T. vivax*.

| Days of Expt. | RBC x $10^6$/mm$^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut. % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 6.63 | 10400 | 10.6 | 31 | 75 | 22 | 1 | 2 | 38.3 |
| 0 | 7.60 | 18000 | 10.6 | 32 | 80 | 19 | 1 | 0 | 38.6 |
| 2 | 7.49 | 15300 | 10.2 | 32 | 78 | 22 | 0 | 0 | 38.7 |
| 4 | 7.40 | 13450 | 10.2 | 31 | 64 | 35 | 0 | 1 | 39.4 |
| 5 | 6.15 | 8000 | 9.2 | 27 | 63 | 37 | 0 | 0 | 39.2 |
| 6 | 5.49 | 6450 | 7.8 | 25 | 49 | 48 | 0 | 3 | 39.2 |
| 7 | 4.20 | 9750 | 7.7 | 23 | 70 | 27 | 2 | 1 | 39.0 |
| 8 | 5.50 | 8750 | 7.2 | 23 | 78 | 22 | 0 | 0 | 39.0 |
| 9 | 5.65 | 11750 | 7.4 | 22 | 73 | 27 | 0 | 0 | 38.8 |
| 10 | 5.40 | 14200 | 7.4 | 22 | 74 | 24 | 0 | 2 | 38.9 |
| 11 | 6.05 | 14500 | 7.0 | 22 | 80 | 20 | 0 | 0 | 39.4 |
| 12 | 5.67 | 12200 | 8.1 | 25 | 78 | 22 | 0 | 0 | 38.4 |
| 14 | 4.51 | 13000 | 8.3 | 25 | 87 | 17 | 1 | 1 | 39.1 |
| 16 | 5.65 | 12550 | 8,0 | 26 | 65 | 34 | 1 | 0 | 39.2 |
| 19 | 5.72 | 13650 | 8.5 | 26 | 77 | 21 | 0 | 2 | 39.6 |
| 21 | 5.00 | 11700 | 7.8 | 25 | 69 | 31 | 0 | 0 | 38.8 |
| 23 | 5.81 | 11600 | 7.8 | 25 | 67 | 33 | 0 | 0 | 38.9 |
| 26 | 5.43 | 8950 | 8.0 | 23 | 81 | 19 | 0 | 0 | 39.4 |
| 28 | 5.50 | 12700 | 8.3 | 24 | 80 | 20 | 0 | 0 | 39.6 |
| 30 | 5.23 | 9400 | 8.0 | 25 | 84 | 16 | 0 | 0 | 39.1 |
| 33 | 6.05 | 8400 | 7.5 | 23 | 73 | 27 | 0 | 0 | 40.4 |
| 37 | 6.41 | 14100 | 8.2 | 25 | 68 | 30 | 1 | 1 | 40.1 |
| 40 | 7.31 | 16000 | 9.3 | 28 | 71 | 29 | 0 | 0 | 39.6 |
| 47 | 5.62 | 15200 | 9.5 | 28 | 82 | 16 | 0 | 2 | 39.1 |
| 54 | 6.47 | 11350 | 9.5 | 28 | 86 | 13 | 0 | 1 | 38.8 |

Table 4 : Haematologic parameters and rectal temperatures in cow No. 15 experimentelly infected with T. vivax.

| Days of Expt. | RBC x $10^6$/mm$^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut. % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 7.04 | 19400 | 11.2 | 33 | 78 | 14 | 4 | 4 | 38.3 |
| 0 | 7.15 | 13600 | 10.4 | 31 | 73 | 24 | 1 | 2 | 38.7 |
| 2 | 6.18 | 9500 | 9.1 | 28 | 65 | 32 | 3 | 0 | 38.8 |
| 4 | 6.77 | 10300 | 8.3 | 25 | 55 | 42 | 2 | 1 | 38.9 |
| 5 | 4.60 | 10450 | 7.2 | 21 | 46 | 53 | 0 | 1 | 39.4 |
| 6 | 4.15 | 12550 | 6.2 | 20 | 47 | 52 | 0 | 1 | 40.6 |
| 7 | 4.06 | 15200 | 7.1 | 20 | 55 | 45 | 0 | 0 | 38.6 |
| 8 | 3.99 | 15850 | 6.8 | 20 | 61 | 38 | 0 | 1 | 39.2 |
| 9 | 3.69 | 13700 | 6.0 | 19 | 54 | 45 | 0 | 1 | 38.7 |
| 10 | 4.22 | 16450 | 6.4 | 20 | 72 | 28 | 0 | 0 | 39.0 |
| 11 | 4.55 | 17600 | 7.0 | 21 | 77 | 21 | 1 | 1 | 38.7 |
| 12 | 3.71 | 16350 | 7.1 | 23 | 86 | 11 | 1 | 2 | 39.1 |
| 14 | 4.34 | 15000 | 8.3 | 24 | 80 | 20 | 0 | 0 | 39.2 |
| 16 | 4.64 | 12950 | 8.5 | 26 | 63 | 33 | 0 | 4 | 39.1 |
| 19 | 5.12 | 18150 | 8.2 | 25 | 76 | 23 | 0 | 1 | 38.8 |
| 21 | 3.87 | 8650 | 5.5 | 18 | 61 | 38 | 0 | 1 | 41.1 |
| 23 | 5.56 | 15550 | 8.0 | 25 | 63 | 35 | 1 | 1 | 39.9 |
| 26 | 5.43 | 16050 | 9.2 | 26 | 85 | 12 | 13 | 0 | 39.6 |
| 28 | 4.56 | 15250 | 8.8 | 25 | 69 | 28 | 2 | 1 | 40.6 |
| 30 | 4.54 | 15400 | 8.0 | 25 | 82 | 17 | 1 | 0 | 39.2 |
| 33 | 4.27 | 18000 | 7.6 | 23 | 77 | 19 | 0 | 4 | 40.4 |
| 35 | 4.76 | 16500 | 7.6 | 25 | 90 | 9 | 1 | 0 | 39.2 |
| 37 | 5.05 | 22500 | 8.7 | 26 | 80 | 17 | 1 | 2 | 39.3 |
| 40 | 4.75 | 20300 | 7.5 | 22 | 78 | 22 | 0 | 0 | 39.1 |
| 47 | 4.60 | 20500 | 8.3 | 25 | 85 | 12 | 2 | 1 | 39.6 |
| 54 | 5.67 | 19950 | 9.5 | 28 | 77 | 12 | 3 | 8 | 40.0 |

Table 5 : Haematologic parameters and rectal temperatures in cow No. 16 experimentally infected with *T. vivax*.

| Days of Expt. | RBC x $10^6$/mm$^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut. % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 5.09 | 16150 | 9.6 | 29 | 75 | 25 | 0 | 0 | 38.4 |
| 0 | 5.90 | 10400 | 10.4 | 30 | 71 | 26 | 0 | 3 | 38.8 |
| 2 | 6.41 | 11850 | 9.8 | 31 | 75 | 23 | 0 | 2 | 38.8 |
| 4 | 6.32 | 8650 | 9.0 | 29 | 50 | 49 | 0 | 1 | 39.4 |
| 5 | 4.49 | 6250 | 7.2 | 21 | 47 | 53 | 0 | 0 | 39.8 |
| 6 | 2.90 | 6250 | 4.5 | 14 | 66 | 31 | 2 | 1 | 40.8 |
| 7 | 2.94 | 7550 | 4.7 | 13 | 69 | 30 | 1 | 0 | 40.3 |
| 8 | 2.72 | 5150 | 4.0 | 12 | 68 | 25 | 3 | 3 | 39.4 |
| 9 | 2.35 | 7650 | 3.8 | 12 | 71 | 29 | 0 | 0 | 39.8 |
| 10 | 2.80 | 8500 | 4.3 | 14 | 70 | 30 | 0 | 0 | 38.6 |
| 11 | 2.32 | 7900 | 4.2 | 15 | 78 | 22 | 0 | 0 | 38.7 |
| 12 | 2.04 | 5450 | 4.1 | 15 | 63 | 37 | 0 | 0 | 39.4 |
| 14 | 2.37 | 8300 | 5.2 | 16 | 80 | 20 | 0 | 0 | 38.9 |
| 16 | 2.94 | 7850 | 5.9 | 18 | 45 | 55 | 0 | 0 | 39.0 |
| 19 | 2.84 | 6500 | 4.5 | 15 | 76 | 22 | 0 | 2 | 40.0 |
| 21 | 1.42 | 9800 | 2.4 | 8 | 89 | 11 | 0 | 0 | 37.8 |

Table 6 : Haematologic parameters and rectal temperatures in cow No. 17 experimentally infected with T. vivax.

| Days of Expt. | RBC x $10^6$/mm$^3$ | W B C | Hb Gm/dl | PCV % | LY % | Neut. % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -2 | 7.40 | 10700 | 9.6 | 29 | 66 | 27 | 5 | 2 | 37.9 |
| 0 | 6.25 | 12300 | 9.8 | 28 | 80 | 19 | 0 | 1 | 38.8 |
| 2 | 6.94 | 11650 | 9.0 | 28 | 76 | 23 | 1 | 0 | 39.2 |
| 4 | 5.84 | 6300 | 7.7 | 23 | 71 | 29 | 0 | 0 | 40.0 |
| 5 | 4.93 | 7950 | 7.4 | 21 | 74 | 25 | 1 | 0 | 40.0 |
| 6 | 3.49 | 8200 | 6.3 | 19 | 54 | 45 | 0 | 1 | 40.4 |
| 7 | 3.84 | 8860 | 5.6 | 17 | 77 | 21 | 2 | 0 | 40.2 |
| 8 | 5.00 | 11150 | 6.0 | 18 | 74 | 24 | 1 | 1 | 40.6 |
| 9 | 4.07 | 10300 | 5.2 | 16 | 71 | 28 | 0 | 1 | 40.0 |
| 10 | 3.40 | 11350 | 5.2 | 17 | 73 | 27 | 0 | 0 | 40.0 |
| 11 | 3.06 | 10800 | 5.2 | 17 | 76 | 24 | 0 | 0 | 39.9 |
| 12 | 3.56 | 10100 | 6.1 | 19 | 79 | 21 | 0 | 0 | 39.1 |
| 14 | 3.41 | 7400 | 5.2 | 16 | 73 | 27 | 0 | 0 | 40.6 |
| 16 | 3.22 | 9950 | 5.9 | 18 | 52 | 44 | 3 | 1 | 40.4 |
| 19 | 3.43 | 10800 | 5.1 | 16 | 60 | 39 | 1 | 0 | 40.4 |
| 21 | 2.76 | 10100 | 3.8 | 13 | 89 | 11 | 0 | 0 | 39.8 |
| 23 | 2.75 | 15800 | 4.9 | 17 | 75 | 21 | 3 | 1 | 39.3 |
| 26 | 3.25 | 9850 | 5.6 | 18 | 86 | 14 | 0 | 0 | 40.0 |
| 28 | 3.14 | 9400 | 6.0 | 17 | 74 | 26 | 0 | 0 | 39.3 |
| 30 | 3.28 | 9050 | 5.0 | 16 | 68 | 31 | 1 | 0 | 39.2 |
| 33 | 2.56 | 14550 | 5.4 | 16 | 78 | 18 | 5 | 1 | 39.3 |
| 35 | 2.75 | 12500 | 5.5 | 16 | 78 | 21 | 0 | 1 | 39.1 |
| 37 | 3.75 | 11850 | 5.7 | 18 | 92 | 7 | 1 | 0 | 39.2 |
| 40 | 3.40 | 12900 | 5.4 | 17 | 69 | 31 | 0 | 0 | 39.3 |
| 47 | 2.46 | 10350 | 4.4 | 14 | 87 | 13 | 0 | 0 | 39.1 |
| 54 | 1.30 | 13650 | 3.7 | 12 | 50 | 50 | 0 | 0 | 37.9 |

Table 7: Haematologic parameters in cow No. 27 experimentally infected with T. vivax.

| Days of Expt. | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | EO % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 30 | 9.6 | 8.03 | 8600 | 61 | 36 | 0 | 3 |
| -1 | 31 | 10.0 | 7.97 | 6950 | 69 | 31 | 0 | 0 |
| 0 | 28 | 8.4 | 8.25 | 6800 | 77 | 22 | 1 | 0 |
| 3 | 30 | 10.0 | 7.54 | 4650 | 64 | 30 | 4 | 2 |
| 5 | 27 | 9.0 | 8.91 | 3100 | 57 | 42 | 0 | 1 |
| 8 | 25 | 8.3 | 7.91 | 4550 | 68 | 30 | 1 | 1 |
| 11 | 25 | 8.4 | 8.84 | 8250 | 81 | 17 | 1 | 1 |
| 12 | 24 | 7.3 | 7.35 | 9400 | 82 | 18 | 0 | 0 |
| 14 | 23 | 7.3 | 7.84 | 6800 | 82 | 9 | 3 | 6 |
| 16 | 23 | 7.2 | - | - | - | - | - | - |
| 18 | 22 | 6.6 | 6.36 | 7700 | 74 | 24 | 1 | 1 |
| 21 | 19 | 6.5 | 6.49 | 9600 | 79 | 18 | 3 | 0 |
| 25 | 20 | 6.3 | 4.92 | 8400 | 52 | 46 | 1 | 1 |
| 28* | 19 | 5.2 | 4.91 | 7500 | 84 | 15 | 1 | 0 |
| 29 | 18 | 5.0 | - | - | - | - | - | - |
| 32 | 19 | 5.0 | 4.36 | 8800 | 89 | 11 | 0 | 0 |
| 36 | 17 | 5.2 | 4.02 | 8350 | 81 | 19 | 0 | 0 |
| 39 | 16 | 4.5 | 4.49 | 7150 | 77 | 21 | 1 | 1 |
| 42 | 20 | 6.6 | 4.97 | 8500 | 74 | 24 | 1 | 1 |
| 46 | 23 | 6.6 | 5.44 | 9800 | 80 | 19 | 1 | 0 |
| 49 | 21 | 6.6 | 4.94 | 8700 | 94 | 5 | 1 | 0 |
| 51 | 20 | 6.5 | - | - | - | - | - | - |
| 54 | 24 | 7.7 | 5.97 | 8150 | 77 | 17 | 0 | 6 |
| 56 | 24 | 8.3 | 5.31 | 6400 | 86 | 13 | 1 | 0 |
| 58 | 26 | 9.0 | - | - | - | - | - | - |
| 61 | 24 | 8.0 | 8.53 | 10750 | 81 | 19 | 0 | 0 |
| 63 | 27 | 8.8 | 7.35 | 10250 | 72 | 25 | 1 | 2 |

Table 8 : Haematologic parameters in cow No. 28 experimentally infected with T. vivax.

| Days of Expt. | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 33 | 10.6 | 8.05 | 7800 | 42 | 56 | 1 | 1 |
| -1 | 22 | 10.6 | 8.45 | 11400 | 60 | 36 | 2 | 2 |
| 0 | 29 | 9.4 | 7.65 | 8000 | 71 | 29 | 0 | 0 |
| 3 | 31 | 10.3 | 9.18 | 8200 | 55 | 40 | 2 | 3 |
| 6 | 31 | 10.0 | 7.59 | 6150 | 54 | 46 | 0 | 0 |
| 9 | 27 | 9.0 | 9.50 | 5700 | 61 | 27 | 1 | 1 |
| 12 | 30 | 9.7 | - | - | - | - | - | - |
| 16 | 28 | 8.3 | 7.84 | 7900 | 64 | 34 | 1 | 1 |
| 16 | 24 | 7.3 | 7.52 | 8050 | - | - | - | - |
| 20 | 24 | 7.3 | 5.63 | 6200 | 85 | 13 | 0 | 2 |
| 22 | 23 | 7.0 | 5.81 | 8800 | 91 | 7 | 0 | 2 |
| 26 | 28 | 8.0 | 7.97 | 11350 | 67 | 32 | 1 | 0 |
| 28 | 26 | 7.7 | 6.45 | 7300 | 77 | 17 | 0 | 6 |
| 32 | 24 | 7.0 | 6.02 | 12450 | 88 | 9 | 2 | 1 |
| 34 | 24 | 8.2 | 7.24 | 12300 | 84 | 14 | 0 | 2 |
| 39 | 24 | 8.0 | 7.82 | 15750 | 92 | 6 | 1 | 1 |
| 42 | 22 | 7.1 | - | - | - | - | - | - |
| 46 | 22 | 6.3 | 5.86 | 13900 | 70 | 28 | 1 | 1 |
| 49 | 20 | 6.1 | 5.25 | 12100 | 70 | 28 | 0 | 2 |
| 51 | 23 | 7.2 | - | - | - | - | - | - |
| 54 | 21 | 6.9 | 5.04 | 12700 | 81 | 18 | 1 | 0 |
| 56 | 23 | 7.2 | 7.10 | 9850 | 89 | 11 | 0 | 0 |
| 58 | 25 | 8.7 | - | - | - | - | - | - |
| 61 | 25 | 8.3 | 7.20 | 10300 | 78 | 19 | 2 | 1 |
| 63 | 22 | 7.1 | - | - | - | - | - | - |

Table 9 : Haematologic parameters in cow No. 29 experimentally infected with *T. vivax*.

| Days of Expt | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 33 | 10.7 | 8.05 | 9700 | 74 | 26 | 0 | 0 |
| -1 | 29 | 9.0 | 8.20 | 6200 | 62 | 34 | 3 | 1 |
| 0 | 29 | 9.4 | 9.69 | 5750 | 69 | 29 | 1 | 1 |
| 3 | 33 | 10.4 | 8.63 | 8250 | 63 | 33 | 2 | 2 |
| 6 | 31 | 10.1 | 8.03 | 3900 | 41 | 55 | 4 | 0 |
| 9 | 30 | 10.0 | 7.82 | 6950 | 86 | 11 | 1 | 2 |
| 11 | 29 | 9.7 | 7.15 | 6850 | 80 | 16 | 2 | 2 |
| 13 | 26 | 8.0 | 7.94 | 7500 | 86 | 10 | 0 | 4 |
| 15 | 27 | 8.0 | - | - | - | - | - | - |
| 18 | 26 | 8.0 | 7.55 | 7300 | 72 | 26 | 1 | 1 |
| 20 | 22 | 6.7 | 8.25 | 8300 | 75 | 22 | 0 | 3 |
| 23 | 21 | 6.8 | 6.15 | 12750 | 85 | 12 | 1 | 2 |
| 25 | 23 | 7.0 | 6.25 | 9750 | 77 | 21 | 1 | 1 |
| 28 | 24 | 7.1 | 6.40 | 9850 | 76 | 24 | 0 | 0 |
| 30 | 26 | 8.0 | 6.03 | 9500 | 77 | 23 | 0 | 0 |
| 33 | 24 | 6.8 | 5.94 | 10550 | 85 | 11 | 1 | 3 |
| 36 | 23 | 7.0 | - | - | - | - | - | - |
| 39 | 25 | 8.0 | 5.98 | 17950 | 68 | 26 | 3 | 3 |
| 42 | 24 | 7.9 | - | - | - | - | - | - |
| 46 | 27 | 8.3 | 7.76 | 10500 | 77 | 23 | 0 | 0 |
| 49 | 25 | 8.5 | 6.05 | 16500 | 70 | 26 | 2 | 2 |
| 54 | 28 | 9.5 | 7.94 | 10050 | 71 | 25 | 2 | 2 |
| 56 | 29 | 10.0 | 8.28 | 16400 | 61 | 39 | 0 | 0 |
| 58 | 34 | 11.6 | - | - | - | - | - | - |
| 61 | 33 | 10.8 | 10.11 | 10800 | 65 | 32 | 2 | 1 |
| 63 | 34 | 11.0 | - | - | - | - | - | - |

Table 10 : Haematologic parameters in cow No. 30 experimentally infected with T. vivax.

| Days of Expt. | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 29 | 9.0 | 7.25 | 5450 | 71 | 23 | 0 | 6 |
| 0 | 27 | 8.2 | 7.00 | 3450 | 71 | 25 | 2 | 2 |
| 3 | 29 | 9.1 | 5.97 | 5700 | 63 | 34 | 1 | 2 |
| 6 | 27 | 7.7 | 5.78 | 3550 | 52 | 0 | 2 | |
| 9 | 25 | 8.2 | 6.00 | 9050 | 78 | 12 | 1 | 4 |
| 11 | 27 | 8.4 | 5.09 | 10800 | 76 | 19 | 0 | 5 |
| 14 | 25 | 8.0 | 6.03 | 10500 | 56 | 42 | 0 | 2 |
| 18 | 23 | 6.9 | 5.31 | 8000 | 72 | 18 | 4 | 6 |
| 20 | 22 | 6.7 | 5.49 | 8350 | 40 | 59 | 1 | 0 |
| 23 | 23 | 7.0 | 6.96 | 11800 | 86 | 13 | 1 | 0 |
| 26 | 23 | 8.0 | 6.85 | 11750 | 70 | 23 | 1 | 1 |
| 29 | 24 | 7.1 | 5.23 | 11550 | 78 | 22 | 0 | 0 |
| 32 | 26 | 7.7 | 5.75 | 19000 | 85 | 14 | 1 | 0 |
| 34 | 26 | 8.0 | 6.23 | 15450 | 88 | 12 | 0 | 0 |
| 36 | 27 | 8.0 | 6.87 | 14750 | 83 | 15 | 1 | 1 |
| 39 | 26 | 8.3 | 7.06 | 16650 | 69 | 31 | 0 | 0 |
| 42 | 21 | 6.8 | - | - | - | - | - | - |
| 46 | 22 | 7.1 | 6.23 | 21150 | 75 | 24 | 1 | 0 |
| 49 | 18 | 6.6 | 5.03 | 12500 | 78 | 21 | 0 | 1 |
| 51 | 17 | 5.8 | - | - | - | - | - | - |
| 54 | 15 | 5.1 | 2.01 | 9200 | 78 | 19 | 0 | 3 |
| 56 | 16 | 5.3 | 2.50 | 9650 | 62 | 36 | 1 | 1 |
| 58 | 18 | 5.5 | - | - | - | - | - | - |
| 61 | 23 | 7.0 | 4.79 | 12750 | 76 | 23 | 1 | - |
| 63 | 22 | 7.1 | - | - | - | - | - | - |

Table 11 : Haematologic parameters in cow No. 31 experimentally infected with T. vivax.

| Days of Expt. | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 33 | 10.6 | 8.65 | 9400 | 51 | 47 | 0 | 2 |
| -1 | 30 | 9.6 | 8.97 | 5500 | 69 | 30 | 1 | 0 |
| 0 | 30 | 9.7 | 9.05 | 5400 | 72 | 26 | 1 | 1 |
| 3 | 33 | 11.0 | 9.79 | 4850 | 62 | 34 | 0 | 4 |
| 6 | 32 | 10.2 | 8.52 | 3050 | 49 | 49 | 1 | 1 |
| 9 | 30 | 10.0 | 9.68 | 7050 | 86 | 10 | 0 | 4 |
| 12 | 28 | 8.7 | 8.02 | 8450 | 75 | 22 | 0 | 3 |
| 14 | 28 | 9.0 | 7.94 | 9750 | 82 | 17 | 1 | 0 |
| 16 | 29 | 9.3 | - | - | - | - | - | - |
| 19 | 27 | 8.5 | 9.17 | 7300 | 79 | 21 | 0 | 0 |
| 21 | 28 | 9.7 | 8.31 | 15700 | 72 | 28 | 0 | 0 |
| 25 | 29 | 8.6 | 8.65 | 10750 | 78 | 21 | 0 | 1 |
| 28 | 24 | 8.0 | 8.94 | 9150 | 68 | 30 | 0 | 2 |
| 30 | 25 | 8.0 | 7.21 | 16950 | 62 | 38 | 0 | 0 |
| 34 | 27 | 8.5 | 8.15 | 9100 | 68 | 31 | 1 | 0 |
| 36 | 25 | 7.3 | - | - | - | - | - | - |
| 39 | 22 | 7.2 | 8.40 | 10150 | 58 | 42 | 0 | 0 |
| 43 | 22 | 6.6 | - | - | - | - | - | - |
| 46 | 25 | 7.1 | 9.03 | 16950 | 77 | 22 | 1 | 0 |
| 49 | 23 | 7.3 | 8.46 | 12500 | 64 | 35 | 1 | 0 |
| 51 | 27 | 7.8 | - | - | - | - | - | - |
| 54 | 26 | 8.3 | 4.76 | 11950 | 74 | 26 | 0 | 0 |
| 56 | 23 | 7.6 | 6.62 | 10750 | 69 | 28 | 0 | 3 |
| 58 | 25 | 7.8 | - | - | - | - | - | - |
| 61 | 25 | 7.7 | 9.19 | 7150 | 78 | 22 | 0 | 0 |
| 63 | 22 | 7.1 | - | - | - | - | - | - |

Table 12 : Haematologic parameters in cow No. 32 experimentally infected with T. vivax.

| Days of Expt | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 28 | 9.0 | 8.15 | 4250 | 53 | 44 | 0 | 3 |
| -1 | 29 | 9.0 | 8.46 | 6550 | 81 | 15 | 0 | 4 |
| 0 | 29 | 9.0 | 8.35 | 7900 | 81 | 13 | 3 | 3 |
| 3 | 31 | 10.2 | 8.63 | 3650 | 58 | 39 | 2 | 1 |
| 6 | 27 | 7.8 | 7.59 | 3400 | 54 | 43 | 0 | 3 |
| 9 | 21 | 6.8 | 5.41 | 8350 | 92 | 6 | 1 | 2 |
| 12 | 21 | 6.3 | 5.76 | 8900 | 85 | 10 | 2 | 3 |
| 14 | 20 | 6.8 | 5.15 | 9250 | 64 | 22 | 6 | 8 |
| 16 | 22 | 7.2 | - | - | - | - | - | - |
| 18 | 22 | 6.4 | 6.05 | 8850 | 65 | 25 | 10 | 0 |
| 20 | 19 | 5.0 | 4.86 | 5000 | 90 | 8 | 1 | 1 |
| 22 | 20 | 5.2 | 3.53 | 6150 | 87 | 12 | 1 | 0 |
| 25 | 21 | 6.0 | 5.34 | 6850 | 87 | 9 | 4 | 0 |
| 28 | 21 | 6.0 | 4.65 | 5700 | 81 | 14 | 4 | 1 |
| 30 | 18 | 6.0 | 3.11 | 7150 | 92 | 7 | 1 | 0 |
| 33 | 16 | 4.8 | - | - | - | - | - | - |
| 36 | 17 | 5.2 | 4.35 | 7100 | 85 | 14 | 1 | 0 |
| 39 | 15 | 4.2 | 2.95 | 6800 | 74 | 26 | 0 | 0 |
| 42 | 16 | 4.5 | - | - | - | - | - | - |
| 44 | 18 | 4.5 | 3.96 | 7450 | 80 | 18 | 1 | 1 |
| 46 | 17 | 5.0 | 3.71 | 8400 | 79 | 19 | 2 | 0 |
| 49 | 16 | 5.2 | 3.47 | 8150 | 84 | 15 | 1 | 0 |
| 51 | 16. | 4.5 | - | - | - | - | - | - |
| 54 | 20 | 6.9 | 3.34 | 6400 | 83 | 15 | 2 | 0 |
| 56 | 22 | 7.0 | 3.81 | 5850 | 84 | 15 | 1 | 0 |
| 58 | 26 | 8.1 | - | - | - | - | - | - |
| 61 | 24 | 7.2 | 4.77 | 5900 | 81 | 19 | 0 | 0 |
| 63 | 26 | 7.5 | - | - | - | - | - | - |

Table 13: SI, UIBC, TIBC and SC in cow No. 12 experimentally infected with *I. vivax*.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 110 | 215 | 325 | 33.8 |
| 0 | 108 | 240 | 360 | 30.0 |
| 1 | 90 | 280 | 370 | 24.3 |
| 2 | 95 | 275 | 370 | 25.6 |
| 4 | 80 | 248 | 328 | 24.3 |
| 5 | 50 | 220 | 270 | 18.5 |
| 6 | 75 | 248 | 323 | 23.2 |
| 7 | 110 | 130 | 240 | 45.8 |
| 8 | 75 | 242 | 317 | 23.6 |
| 9 | 75 | 228 | 303 | 24.7 |
| 10 | 55 | 220 | 275 | 20.0 |
| 11 | 118 | 175 | 293 | 40.2 |
| 12 | 90 | 250 | 340 | 26.4 |
| 14 | 90 | 170 | 160 | 34.6 |
| 16 | 126 | 185 | 311 | 40.5 |
| 19 | 100 | 240 | 340 | 29.4 |
| 21 | 100 | 270 | 370 | 27.0 |
| 23 | 100 | 335 | 435 | 22.9 |
| 26 | 140 | 170 | 310 | 45.1 |
| 28 | 55 | 275 | 430 | 12.7 |
| 30 | 110 | 205 | 315 | 34.9 |
| 33 | 160 | 205 | 363 | 43.8 |
| 37 | 175 | 220 | 395 | 44.3 |
| 40 | 225 | 180 | 405 | 55.5 |
| 47 | 185 | 200 | 385 | 48.0 |

Table 14: SI, UIBC, TIBC and SC in cow No. 13 experimentally infected with *T. vivax*.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 150 | 200 | 350 | 42.5 |
| 0 | 132 | 175 | 307 | 42.9 |
| 2 | 115 | 178 | 293 | 39.2 |
| 4 | 40 | 168 | 208 | 19.2 |
| 6 | 50 | 200 | 250 | 20.0 |
| 7 | 100 | 175 | 275 | 36.3 |
| 8 | 60 | 160 | 220 | 27.2 |
| 9 | 118 | 200 | 318 | 37.1 |
| 10 | 95 | 115 | 210 | 45.2 |
| 11 | 92 | 134 | 226 | 41.0 |
| 12 | 120 | 90 | 210 | 57.1 |
| 14 | 110 | 135 | 245 | 44.8 |
| 19 | 126 | 132 | 258 | 48.8 |
| 21 | 118 | 140 | 258 | 45.7 |
| 23 | 205 | 160 | 365 | 58.9 |
| 26 | 114 | 147 | 261 | 43.6 |
| 28 | 126 | 147 | 273 | 46.1 |
| 30 | 108 | 132 | 240 | 45.0 |
| 33 | 70 | 180 | 250 | 28.0 |
| 37 | 105 | 110 | 215 | 48.8 |
| 40 | 90 | 100 | 190 | 47.3 |
| 47 | 110 | 120 | 230 | 47.8 |

Table 15 : SI, UIBC, TIBC and SC in cow No. 14 experimentally infected with T. vivax.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 140 | 190 | 330 | 42.4 |
| 0 | 155 | 230 | 385 | 40.2 |
| 1 | 145 | 200 | 345 | 42.0 |
| 2 | 115 | 220 | 355 | 34.3 |
| 4 | 80 | 185 | 265 | 30.2 |
| 5 | 70 | 170 | 240 | 29.1 |
| 6 | 70 | 190 | 260 | 26.9 |
| 7 | 110 | 180 | 290 | 37.9 |
| 8 | 60 | 180 | 240 | 25.0 |
| 9 | 50 | 360 | 410 | 12.1 |
| 10 | 140 | 160 | 300 | 46.6 |
| 12 | 152 | 175 | 325 | 46.7 |
| 14 | 100 | 210 | 310 | 32.2 |
| 16 | 95 | 155 | 250 | 38.0 |
| 19 | 125 | 200 | 325 | 38.4 |
| 21 | 92 | 175 | 267 | 34.5 |
| 23 | 125 | 175 | 300 | 41.6 |
| 26 | 212 | 120 | 332 | 63.8 |
| 28 | 100 | 200 | 300 | 33.3 |
| 30 | 90 | 205 | 295 | 30.5 |
| 33 | 90 | 250 | 340 | 26.4 |
| 37 | 112 | 185 | 297 | 37.7 |
| 40 | 155 | 155 | 310 | 50.0 |

Table 16 : SI, UIBC, TIBC and SC in cow No. 15 experimentally infected with T. vivax.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 110 | 140 | 250 | 44.0 |
| 0 | 135 | 160 | 295 | 45.7 |
| 2 | 95 | 194 | 289 | 32.8 |
| 4 | 100 | 165 | 265 | 37.8 |
| 5 | 25 | 188 | 213 | 11.7 |
| 7 | 115 | 120 | 235 | 48.9 |
| 8 | 120 | 120 | 240 | 50.0 |
| 9 | 68 | 180 | 248 | 27.4 |
| 10 | 142 | 125 | 267 | 53.2 |
| 11 | 115 | 165 | 280 | 41.0 |
| 14 | 132 | 130 | 262 | 50.4 |
| 16 | 105 | 180 | 285 | 36.8 |
| 19 | 158 | 165 | 323 | 48.9 |
| 21 | 94 | 160 | 254 | 37.0 |
| 23 | 128 | 145 | 273 | 46.8 |
| 26 | 120 | 175 | 295 | 40.6 |
| 28 | 94 | 175 | 269 | 34.9 |
| 30 | 158 | 200 | 358 | 44.1 |
| 33 | 96 | 254 | 350 | 27.4 |
| 35 | 122 | 150 | 272 | 44.8 |
| 37 | 130 | 165 | 295 | 44.0 |
| 40 | 310 | 170 | 480 | 64.5 |
| 47 | 122 | 180 | 302 | 40.3 |
| 54 | 90 | 30 | 120 | 75.0 |

Table 17 : SI, UIBC, TIBC and SC in cow No. 16 experimentally infected with T. vivax.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 120 | 205 | 325 | 36.9 |
| 0 | 125 | 220 | 345 | 36.2 |
| 2 | 110 | 240 | 350 | 31.4 |
| 4 | 25 | 225 | 250 | 10.0 |
| 5 | 45 | 190 | 235 | 19.1 |
| 7 | 80 | 220 | 300 | 26.6 |
| 8 | 155 | 140 | 295 | 52.5 |
| 9 | 188 | 140 | 328 | 57.3 |
| 10 | 185 | 40 | 225 | 82.2 |
| 11 | 135 | 145 | 280 | 48.2 |
| 12 | 85 | 120 | 205 | 41.4 |
| 19 | 162 | 105 | 267 | 53.2 |

Table 18 : SI, UIBC, TIBC and SC in cow No. 17 experimentally infected with *T. vivax*.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 130 | 200 | 330 | 39.3 |
| 0 | 145 | 170 | 315 | 46.0 |
| 1 | 120 | 170 | 290 | 41.3 |
| 2 | 85 | 150 | 235 | 36.1 |
| 4 | 80 | 120 | 200 | 40.0 |
| 5 | 70 | 165 | 235 | 29.7 |
| 6 | 87 | 115 | 202 | 43.0 |
| 7 | 105 | 95 | 200 | 52.5 |
| 8 | 95 | 65 | 160 | 59.4 |
| 9 | 150 | 110 | 260 | 57.9 |
| 10 | 158 | 140 | 298 | 53.0 |
| 11 | 120 | 115 | 235 | 51.0 |
| 12 | 110 | 160 | 270 | 40.7 |
| 14 | 85 | 130 | 215 | 39.5 |
| 16 | 152 | 130 | 282 | 53.9 |
| 19 | 148 | 100 | 248 | 59.6 |
| 21 | 135 | 60 | 195 | 69.2 |
| 23 | 275 | 60 | 335 | 82.0 |
| 26 | 132 | 140 | 272 | 48.5 |
| 28 | 140 | 95 | 235 | 59.5 |
| 30 | 165 | 100 | 265 | 62.3 |
| 33 | 160 | 100 | 260 | 61.5 |
| 35 | 140 | 100 | 240 | 58.3 |
| 37 | 100 | 195 | 295 | 33.8 |
| 40 | 115 | 100 | 215 | 53.4 |
| 47 | 205 | 65 | 270 | 75.9 |

Table 19 : SI, UIBC, TIBC and SC in cow No. 27 experimentally infected with T. vivax.

| Days of Expt | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 112.5 | 100.0 | 212.5 | 52.9 |
| 0 | 92.5 | 150.0 | 242.5 | 38.1 |
| 3 | 106.5 | 117.5 | 224.0 | 47.5 |
| 7 | 62.5 | 100.0 | 162.5 | 38.5 |
| 11 | 62.5 | 94.0 | 156.5 | 39.9 |
| 13 | 112.5 | 100.0 | 212.5 | 52.9 |
| 16 | 122.5 | 80.0 | 202.5 | 60.5 |
| 20 | 117.5 | 94.0 | 211.5 | 55.6 |
| 25 | 72.5 | 94.0 | 166.5 | 43.5 |
| 29 | 150.0 | 50.0 | 200.0 | 75.0 |
| 34 | 135.0 | 94.0 | 229.0 | 58.9 |
| 37 | 122.5 | 117.5 | 240.0 | 51.0 |
| 42 | 127.5 | 107.5 | 235.0 | 54.3 |
| 46 | 100.0 | 100.0 | 200.0 | 50.0 |
| 49 | 100.0 | 100.0 | 200.0 | 50.0 |
| 53 | 77.5 | 117.5 | 195.0 | 39.7 |
| 55 | 106.5 | 94.0 | 200.5 | 53.0 |
| 61 | 100.0 | 94.0 | 194.0 | 51.6 |
| 63 | 106.3 | 67.5 | 174.0 | 61.2 |

Table 20: SI, UIBC, TIBC and SC in cow No. 28 experimentally infected with T. vivax.

| Days of Expt. | $S_I$ ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 85.0 | 194.0 | 279.0 | 30.5 |
| 0 | 106.5 | 170 .5 | 276 .0 | 26.0 |
| 3 | 72.5 | 127.5 | 200.0 | 36.3 |
| 7 | 72.5 | 117.5 | 190.0 | 38.2 |
| 11 | 77.5 | 117.5 | 195.0 | 39.7 |
| 13 | 112.5 | 100.0 | 212.5 | 52.9 |
| 16 | 85.0 | 140.0 | 225.0 | 37.8 |
| 20 | 85.0 | 44.0 | 129.0 | 65.9 |
| 25 | 92.5 | 94.0 | 186.5 | 49.6 |
| 29 | 85.0 | 127.5 | 212.5 | 40.0 |
| 34 | 92.5 | 94.0 | 186.5 | 49.6 |
| 37 | 85.0 | 150.0 | 235.0 | 36.2 |
| 42 | 122.5 | 117.5 | 240.0 | 51.0 |
| 46 | 100.0 | 107.5 | 207.5 | 48.2 |
| 49 | 100.0 | 100.0 | 200.0 | 50.0 |
| 53 | 90.0 | 141.5 | 231.5 | 38.9 |
| 55 | 100.0 | 94.0 | 194.0 | 51.6 |
| 61 | 100.0 | 100.0 | 200.0 | 50.0 |
| 63 | 90.0 | 100.0 | 190.0 | 47.4 |

Table 21 : SI, UIBC, TIBC and SC in cow No. 29 experimentally infected with T. vivax.

| Days of Expt. | S I ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| **-1** | 140.0 | 160.0 | 300.0 | 46.7 |
| **0** | 150.0 | 150.0 | 300.0 | 50.0 |
| **3** | 127.5 | 94.0 | 221.5 | 57.6 |
| **7** | 145.0 | 57.5 | 202.5 | 71.6 |
| **11** | 100.0 | 80.0 | 180.0 | 55.6 |
| **13** | 145.0 | 22.0 | 167.0 | 86.8 |
| **16** | 135.0 | 127.5 | 262.5 | 51.4 |
| **20** | 112.5 | 94.0 | 206.5 | 54.5 |
| **25** | 150.0 | 57.5 | 207.5 | 72.3 |
| **29** | 112.5 | 80.0 | 192.5 | 58.4 |
| **34** | 135.0 | 44.0 | 179.0 | 75.4 |
| **37** | 122.5 | 27.5 | 150.0 | 81.7 |
| **42** | 145.0 | 100.0 | 145.0 | 58.4 |
| **46** | 106.0 | 50.0 | 156.0 | 67.9 |
| **49** | 100.0 | 94.0 | 194.0 | 51.6 |
| **53** | 100.0 | 80.0 | 180.0 | 55.6 |
| **55** | 106.5 | 80.0 | 186.5 | 57.1 |
| **61** | 122.5 | 50.0 | 132.5 | 71.0 |
| **63** | 127.5 | 27.5 | 155.0 | 82.3 |

Table 22 : SI, UIBC, TIBC and SC in cow 30 experimentally infected with T. vivax.

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 80.0 | 120.0 | 200.0 | 40.0 |
| 0 | 56.5 | 157.0 | 213.5 | 48.9 |
| 3 | 92.5 | 127.5 | 220.0 | 42.1 |
| 7 | 106.5 | 20.0 | 126.5 | 84.2 |
| 11 | 92.5 | 80.0 | 172.5 | 53.6 |
| 13 | 100.0 | 40.0 | 140.0 | 71.4 |
| 16 | 62.5 | 127.5 | 190.0 | 32.9 |
| 20 | 145.0 | 67.5 | 212.5 | 68.2 |
| 25 | 112.5 | 80.0 | 192.5 | 58.4 |
| 29 | 112.5 | 94.0 | 206.5 | 54.5 |
| 34 | 135.0 | 44.0 | 179.0 | 75.4 |
| 37 | 145.0 | 80.0 | 225.0 | 64.4 |
| 42 | 145.0 | 100.0 | 245.0 | 59.2 |
| 46 | 145.0 | 50.0 | 195.0 | 74.4 |
| 49 | 155.0 | 57.5 | 212.5 | 72.9 |
| 53 | 145.0 | 100.0 | 245.0 | 59.2 |
| 55 | 150.0 | 50.0 | 200.0 | 75.0 |
| 61 | 137.5 | 80.0 | 217.5 | 63.2 |
| 63 | 127.5 | 57.5 | 185.0 | 68.9 |

Table 23 : SI, UIBC, TIBC and SC in cow 31 experimentally infected with T. vivax.

| Days of Expt | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 90.0 | 130.0 | 220.0 | 40.9 |
| 0 | 92.5 | 190.0 | 282.5 | 30.6 |
| 3 | 112.5 | 150.0 | 262.5 | 42.9 |
| 7 | 145.0 | 44.0 | 189.0 | 76.7 |
| 11 | 77.5 | 140.0 | 217.5 | 35.6 |
| 13 | 90.0 | 100.0 | 190.0 | 47.4 |
| 16 | 106.5 | 100.0 | 206.5 | 51.6 |
| 20 | 112.5 | 80.0 | 192.5 | 58.4 |
| 25 | 77.5 | 100.0 | 177.5 | 43.7 |
| 29 | 92.5 | 127.5 | 220.0 | 42.1 |
| 34 | 90.0 | 100.0 | 190.0 | 47.4 |
| 37 | 85.0 | 140.0 | 225.0 | 37.8 |
| 42 | 100.0 | 127.5 | 227.5 | 43.4 |
| 46 | 90.0 | 117.5 | 207.5 | 43.4 |
| 49 | 117.5 | 100.0 | 217.5 | 54.0 |
| 53 | 67.5 | 180.0 | 247.5 | 27.3 |
| 55 | 85.0 | 117.5 | 202.5 | 41.9 |
| 61 | 127.5 | 100.0 | 227.5 | 56.0 |
| 63 | 112.5 | 94.0 | 206.5 | 54.5 |

Table 24 : S I, UIBC, TIBC and SC in cow 32 experimentally infected with T. vivax.

| Days of Expt | S I ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 127.5 | 100.0 | 227.5 | 56.0 |
| 0 | 120.0 | 160.0 | 280.0 | 42.9 |
| 3 | 100.0 | 230.0 | 330.0 | 30.3 |
| 7 | 122.5 | 20.0 | 142.5 | 86.9 |
| 11 | 135.0 | 117.5 | 252.5 | 53.5 |
| 13 | 133.0 | 100.0 | 233.0 | 57.1 |
| 16 | 100.0 | 157.5 | 257.5 | 38.8 |
| 20 | 106.5 | 94.0 | 200.5 | 53.1 |
| 25 | 112.5 | 94.0 | 206.5 | 54.5 |
| 29 | 122.5 | 80.0 | 202.5 | 60.5 |
| 34 | 135.0 | 80.0 | 215.0 | 62.8 |
| 37 | 145.0 | 100.0 | 245.0 | 59.2 |
| 42 | 155.0 | 50.0 | 200.0 | 77.5 |
| 46 | 140.0 | 60.0 | 200.0 | 70.0 |
| 49 | 150.0 | 57.5 | 207.5 | 72.3 |
| 53 | 135.0 | 100.0 | 235.0 | 57.5 |
| 55 | 112.5 | 150.0 | 262.5 | 42.9 |
| 61 | 145.0 | 101.5 | 246.5 | 58.8 |
| 63 | 112.5 | 100.0 | 212.5 | 52.9 |

# APPENDIX 5: HAEMATOLOGY, SI, UIBC, TIBC AND SC OF UNINFECTED ZEBU CATTLE

Table 1 : Haematologic parameters in control cow No. 18

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | W B C | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -2 | 29.0 | 9.6 | 6.75 | 9,400 | 61 | 35 | 3 | 1 |
| 0 | 32.0 | 11.0 | 6.47 | 8,400 | 57 | 34 | 9 | 0 |
| 7 | 29.0 | 9.5 | 6.33 | 10,200 | 72 | 19 | 9 | 0 |
| 14 | 28.0 | 9.4 | 4.62 | 10,100 | 79 | 17 | 3 | 1 |
| 21 | 27.0 | 9.2 | 5.46 | 8,350 | 62 | 32 | 4 | 2 |
| 28 | 28.0 | 9.8 | 5.23 | 11,400 | 63 | 30 | 2 | 5 |
| 35 | 32.0 | 10.9 | 5.15 | 15,250 | 64 | 28 | 4 | 4 |
| 42 | 29.0 | 9.9 | 5.69 | 7,550 | 59 | 35 | 5 | 1 |
| 49 | 30.0 | 10.2 | 5.21 | 12,850 | 60 | 27 | 11 | 2 |
| 56 | 30.0 | 10.3 | 5.18 | 11,250 | 54 | 35 | 11 | 0 |
| 63 | 29.0 | 10.0 | 5.94 | 12,850 | 61 | 33 | 6 | 0 |

Table 2 : Haematologic parameters in control cow No. 19

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6/mm^3$ | W B C | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -2 | 30.0 | 9.9 | 7.90 | 18,200 | 75 | 22 | 2 | 1 |
| 0 | 31.0 | 10.4 | 7.18 | 18,250 | 75 | 22 | 2 | 1 |
| 7 | 30.0 | 9.8 | 6.75 | 19,250 | 72 | 22 | 6 | 0 |
| 14 | 30.0 | 9.9 | 7.79 | 20,000 | 81 | 16 | 0 | 3 |
| 21 | 30.0 | 10.3 | 6.64 | 21,500 | 62 | 33 | 3 | 2 |
| 28 | 28.0 | 9.2 | 5.67 | 18,250 | 78 | 20 | 1 | 1 |
| 35 | 29.0 | 9.4 | 7.76 | 15,750 | 75 | 24 | 1 | 0 |
| 42 | 28.0 | 9.2 | 5.82 | 22,750 | 74 | 24 | 1 | 1 |
| 49 | 29.0 | 9.6 | 6.11 | 22,900 | 64 | 30 | 2 | 4 |
| 56 | 28.0 | 9.0 | 5.48 | 21,100 | 78 | 20 | 2 | 0 |
| 63 | 29.0 | 9.6 | 5.28 | 20.350 | 76 | 21 | 2 | 1 |

Table 3 ; Haematologic parameters in control cow No. 20

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | W B C | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -2 | 41.0 | 13.5 | 10.40 | 12,750 | 61 | 38 | 0 | 1 |
| 0 | 30.0 | 10.0 | 8.35 | 11,650 | 63 | 37 | 0 | 0 |
| 7 | 35.0 | 12.0 | 9.41 | 6,300 | 61 | 38 | 1 | 0 |
| 14 | 32.0 | 10.5 | 6.91 | 10,600 | 74 | 20 | 0 | 6 |
| 21 | 34.0 | 11.3 | 9.85 | 9,800 | 82 | 14 | 2 | 2 |
| 28 | 31.0 | 10.5 | 6.32 | 7,700 | 84 | 14 | 1 | 1 |
| 35 | 33.0 | 11.2 | 7.24 | 10,550 | 81 | 15 | 0 | 4 |
| 42 | 28.0 | 9.8 | 6.44 | 7.250 | 82 | 17 | 0 | 1 |
| 49 | 30.0 | 10.2 | 6.17 | 11,300 | 78 | 19 | 1 | 2 |
| 56 | 29.0 | 9.8 | 6.56 | 10,600 | 74 | 23 | 1 | 2 |
| 63 | 30.0 | 10.2 | 5.23 | 9,750 | 81 | 15 | 0 | 4 |

Table 5 : SI, UIBC, TIBC and SC values in control cow No. 18

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 125 | 210 | 335 | 37.3 |
| 0 | 137 | 190 | 327 | 41.9 |
| 7 | 118 | 240 | 359 | 32.8 |
| 14 | 150 | 240 | 390 | 38.5 |
| 21 | 122 | 220 | 342 | 35.6 |
| 28 | 145 | 200 | 345 | 42.0 |
| 35 | 137 | 260 | 397 | 34.5 |
| 42 | 145 | 230 | 375 | 38.7 |
| 49 | 122 | 200 | 322 | 37.9 |
| 56 | 137 | 190 | 327 | 41.9 |
| 63 | 120 | 240 | 360 | 33.3 |

Table 6 : SI, UIBC, TIBC and SC values in control cow No. 19

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 135 | 220 | 355 | 38.0 |
| 0 | 137 | 200 | 337 | 40.6 |
| 7 | 145 | 150 | 295 | 49.1 |
| 14 | 130 | 190 | 320 | 40.6 |
| 21 | 118 | 200 | 318 | 37.1 |
| 28 | 100 | 230 | 330 | 30.3 |
| 35 | 120 | 180 | 300 | 40.0 |
| 42 | 135 | 210 | 345 | 39.1 |
| 49 | 122 | 170 | 292 | 41.8 |
| 56 | 100 | 210 | 310 | 32.3 |
| 63 | 117 | 200 | 317 | 36.9 |

Table 7 : SI, UIBC, TIBC and SC values in control cow No. 20

| Days of Expt. | SI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -2 | 122 | 190 | 312 | 39.1 |
| 0 | 118 | 158 | 276 | 42.8 |
| 7 | 135 | 200 | 335 | 40.3 |
| 14 | 137 | 157 | 294 | 46.6 |
| 21 | 116 | 140 | 256 | 45.3 |
| 28 | 112 | 180 | 300 | 37.3 |
| 35 | 150 | 180 | 330 | 45.4 |
| 42 | 118 | 140 | 258 | 45.7 |
| 49 | 112 | 180 | 292 | 38.4 |
| 56 | 110 | 200 | 310 | 35.5 |
| 63 | 122 | 138 | 260 | 46.9 |

# APPENDIX 6: HAEMATOLOGY, PI, UIBC, TIBC AND SC IN ZEBU CATTLE WITH *T. CONGOLENSE* INFECTION

Table 1 : Haematologic parameters and rectal temperatures in cow No. 22 experimentally infected with T. congolense.

| Days of Expt. | RBC x $10^6$/$mm^3$ | WBC | Hb Gm/dl | PCV % | LY % | Seg % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 6.52 | 10400 | 9.7 | 29 | 62 | 31 | 6 | 1 | 38.8 |
| 6 | 6.02 | 11400 | 9.5 | 28 | 67 | 22 | 11 | 0 | 38.7 |
| - | 7.19 | 12350 | 8.6 | 28 | 72 | 21 | 6 | 1 | 38.3 |
| 3 | 8.09 | 9150 | 9.0 | 28 | 68 | 22 | 10 | 0 | 38.8 |
| 4 | 7.70 | 10250 | 10.2 | 30 | 74 | 12 | 1 | 1 | 38.9 |
| 6 | 7.27 | 7500 | 10.8 | 33 | 72 | 25 | 3 | 0 | 40.0 |
| 7 | 7.49 | 8950 | 10.6 | 33 | 68 | 29 | 2 | 1 | 39.4 |
| 8 | 7.10 | 6100 | 9.1 | 29 | 75 | 23 | 2 | 0 | 39.7 |
| 9 | 4.92 | 8950 | 8.0 | 25 | 70 | 27 | 3 | 0 | 39.1 |
| 10 | 6.63 | 9100 | 9.2 | 29 | 75 | 13 | 7 | 5 | 39.1 |
| 11 | 7.47 | 8100 | 9.1 | 27 | 63 | 37 | 0 | 0 | 38.4 |
| 14 | 6.66 | 8800 | 7.2 | 24 | 69 | 26 | 4 | 1 | 39.2 |
| 19 | 4.95 | 5850 | 6.5 | 20 | 71 | 23 | 5 | 2 | 39.2 |
| 21 | 4.76 | 13350 | 6.5 | 21 | 70 | 24 | 1 | 5 | 38.9 |
| 24 | 5.94 | 9250 | 7.0 | 21 | 77 | 23 | 0 | 0 | 39.1 |
| 26 | 4.99 | 9100 | 7.1 | 23 | 86 | 12 | 2 | 0 | 39.2 |
| 28 | 5.45 | 14150 | 6.5 | 21 | 86 | 13 | 1 | 0 | 39.0 |
| 32 | 5.53 | 11950 | 6.8 | 22 | 80 | 15 | 2 | 5 | 38.9 |
| 34 | 4.64 | 10000 | 6.0 | 21 | 78 | 19 | 1 | 2 | 39.8 |
| 38 | 5.09 | 11300 | 6.2 | 20 | 93 | 5 | 2 | 0 | 39.4 |
| 42 | 4.65 | 11800 | 6.0 | 20 | 89 | 9 | 0 | 2 | 39.1 |
| 45 | 4.05 | 11500 | 5.0 | 15 | 87 | 12 | 0 | 1 | 39.7 |
| 48 | 2.70 | 13700 | 3.5 | 14 | 80 | 19 | 0 | 1 | 38.9 |
| 51 | 1.80 | 12850 | 3.5 | 13 | 68 | 31 | 0 | 1 | 39.6 |
| 54 | 1.80 | 9000 | 2.9 | 13 | 61 | 37 | 0 | 2 | 39.2 |
| 58 | 2.11 | 10450 | 3.5 | 13 | 72 | 25 | 1 | 2 | 39.4 |
| 60 | 1.74 | 9250 | 3.5 | 12 | 63 | 34 | 0 | 3 | 38.9 |

Table 2 : *Haematologic parameters and rectal temperatures in cow No. 23 experimentally infected with* T. congolense.

| Days of Expt. | RBC x $10^6$/mm$^3$ | WBC | Hb Gm/dl | PCV % | LY % | Seg % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -8 | 6.54 | 17000 | 10.2 | 30 | 74 | 25 | 1 | 0 | 38.8 |
| -6 | 5.83 | 16300 | 10.5 | 31 | 86 | 14 | 0 | 0 | 38.4 |
| 0 | 6.00 | 17150 | 9.8 | 29 | 74 | 23 | 3 | 0 | 38.3 |
| 3 | 6.52 | 12850 | 8.9 | 27 | 74 | 10 | 7 | 0 | 38.4 |
| 4 | 5.70 | 15800 | 8.5 | 27 | 84 | 15 | 0 | 1 | 38.7 |
| 6 | 5.56 | 8250 | 9.9 | 29 | 85 | 13 | 2 | 0 | 38.9 |
| 7 | 5.48 | 11150 | 9.5 | 28 | 69 | 30 | 1 | 0 | 40.2 |
| 8 | 5.23 | 11250 | 8.1 | 27 | 85 | 14 | 0 | 1 | 39.2 |
| 9 | 5.57 | 8800 | 7.0 | 23 | 84 | 13 | 1 | 3 | 38.6 |
| 10 | 5.50 | 11050 | 9.2 | 29 | 92 | 7 | 0 | 1 | 38.1 |
| 11 | 6.95 | 10400 | 9.1 | 27 | 84 | 14 | 1 | 1 | 38.6 |
| 14 | 6.93 | 9200 | 7.2 | 23 | 94 | 3 | 2 | 1 | 38.9 |
| 17 | 5.95 | 10250 | 7.2 | 22 | 87 | 13 | 0 | 0 | 39.1 |
| 19 | 5.30 | 11700 | 7.6 | 22 | 89 | 10 | 1 | 0 | 38.7 |
| 21 | 5.53 | 14900 | 7.3 | 21 | 84 | 15 | 1 | 0 | 38.6 |
| 24 | 5.75 | 12150 | 7.8 | 22 | 93 | 7 | 0 | 0 | 38.9 |
| 26 | 3.83 | 11000 | 7.0 | 20 | 90 | 8 | 2 | 0 | 38.9 |
| 28 | 4.17 | 14550 | 6.2 | 20 | 86 | 14 | 0 | 0 | 38.9 |
| 32 | 3.92 | 10350 | 6.1 | 20 | 94 | 3 | 1 | 2 | 38.9 |
| 38 | 4.36 | 13050 | 6.2 | 20 | 96 | 4 | 0 | 0 | 38.9 |
| 42 | 3.78 | 11400 | 5.2 | 17 | 94 | 4 | 0 | 2 | 38.3 |
| 45 | 3.65 | 1220 | 6.4 | 19 | 86 | 13 | 1 | 0 | 38.9 |
| 48 | 3.20 | 10650 | 5.8 | 18 | 96 | 4 | 0 | 0 | 38.7 |
| 51 | 3.76 | 10350 | 5.0 | 16 | 88 | 12 | 0 | 0 | 38.7 |
| 54 | 4.47 | 10850 | 4.8 | 17 | 80 | 19 | 1 | 0 | 38.3 |
| 58 | 3.64 | 11600 | 5.8 | 19 | 75 | 19 | 2 | 4 | 38.6 |
| 60 | 3.87 | 12850 | 5.0 | 15 | 86 | 11 | 2 | 1 | 38.4 |
| 61 | 3.32 | 10600 | 5.0 | 16 | 86 | 13 | 1 | 0 | 38.9 |

Table 3: Haematologic parameters and rectal temperatures in cow No. 24 experimentally infected with T. congolense.

| Days of Expt. | RBC x $10^6$/mm$^3$ | WBC | Hb Gm/dl | PCV % | LY % | Seg % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -8 | 6.76 | 9500 | 9.9 | 28 | 56 | 26 | 17 | 1 | 38.7 |
| -6 | 5.80 | 10000 | 10.5 | 29 | 61 | 21 | 16 | 2 | 38.9 |
| 0 | 5.13 | 7000 | 9.1 | 27 | 66 | 26 | 8 | 0 | 38.8 |
| 3 | 6.51 | 12600 | 9.0 | 27 | 72 | 17 | 10 | 1 | 38.7 |
| 4 | 5.95 | 7100 | 8.2 | 23 | 77 | 17 | 6 | 0 | 38.9 |
| 6 | 5.46 | 5950 | 7.9 | 24 | 57 | 38 | 5 | 0 | 39.5 |
| 7 | 5.40 | 6000 | 7.0 | 23 | 55 | 37 | 6 | 2 | 40.1 |
| 8 | 4.28 | 7900 | 7.4 | 22 | 68 | 23 | 7 | 2 | 40.0 |
| 9 | 5.24 | 9600 | 8.0 | 24 | 70 | 22 | 7 | 1 | 39.1 |
| 10 | 5.30 | 6500 | 8.3 | 26 | 65 | 20 | 12 | 3 | 39.2 |
| 11 | 5.60 | 7500 | 8.2 | 24 | 64 | 27 | 6 | 3 | 39.7 |
| 14 | 5.80 | 6700 | 6.8 | 21 | 62 | 32 | 6 | 0 | 39.4 |
| 17 | 6.00 | 8800 | 6.6 | 20 | 64 | 33 | 2 | 1 | 40.0 |
| 19 | 4.00 | 5500 | 6.0 | 18 | 62 | 32 | 6 | 0 | 39.4 |
| 21 | 3.95 | 9550 | 5.6 | 18 | 50 | 49 | 1 | 0 | 39.6 |
| 24 | 3.45 | 4600 | 5.5 | 16 | 63 | 34 | 2 | 1 | 39.7 |
| 26 | 3.03 | 5750 | 4.6 | 16 | 75 | 21 | 4 | 0 | 40.1 |
| 28 | 3.89 | 6650 | 5.4 | 17 | 71 | 19 | 9 | 1 | 39.8 |
| 32 | 2.75 | 7300 | 5.0 | 17 | 77 | 20 | 2 | 1 | 39.1 |
| 34 | 4.84 | 10400 | 5.6 | 19 | 80 | 16 | 3 | 1 | 39.1 |
| 38 | 3.65 | 5950 | 5.7 | 10 | 79 | 14 | 4 | 3 | 39.4 |
| 42 | 3.38 | 6200 | 5.5 | 18 | 72 | 22 | 5 | 1 | 39.4 |
| 45 | 3.25 | 6250 | 5.5 | 18 | 78 | 17 | 3 | 2 | 39.4 |
| 48 | 2.59 | 9000 | 4.5 | 15 | 76 | 16 | 6 | 2 | 39.2 |
| 51 | 2.72 | 5900 | 5.0 | 17 | 83 | 16 | 0 | 1 | 40.0 |
| 54 | 3.61 | 11600 | 5.0 | 18 | 82 | 16 | 1 | 1 | 39.1 |
| 58 | 3.23 | 9350 | 5.8 | 18 | 68 | 29 | 1 | 2 | 38.9 |
| 60 | 3.59 | 8000 | 5.0 | 17 | 61 | 39 | 0 | 0 | 38.9 |
| 61 | 2.52 | 7900 | 4.5 | 15 | 53 | 46 | 1 | 0 | 38.9 |

Table 4 : Haematologic parameters and rectal temperatures in cow No. 25 experimentally infected with T. congolense.

| Days of Expt. | RBC x $10^6$/mm$^3$ | WBC | Hb Gm/dl | PCV % | LY % | Seg % | Eo % | Mono % | Temp. °C |
|---|---|---|---|---|---|---|---|---|---|
| -8 | 7.65 | 8150 | 12.4 | 36 | 48 | 40 | 3 | 9 | 38.8 |
| -6 | 8.95 | 9500 | 12.6 | 37 | 52 | 37 | 7 | 4 | 38.6 |
| 0 | 7.16 | 7800 | 10.3 | 31 | 70 | 24 | 6 | 0 | 39.2 |
| 3 | 7.83 | 4500 | 10.0 | 30 | 55 | 38 | 7 | 0 | 38.9 |
| 4 | 7.35 | 6350 | 10.2 | 29 | 72 | 26 | 2 | 0 | 38.9 |
| 6 | 7.17 | 5350 | 10.5 | 31 | 70 | 28 | 1 | 1 | 39.4 |
| 7 | 8.58 | 5750 | 11.2 | 32 | 70 | 24 | 2 | 4 | 39.0 |
| 8 | 6.04 | 5350 | 10.5 | 31 | 56 | 42 | 0 | 2 | 39.2 |
| 9 | 7.62 | 6400 | 9.9 | 29 | 70 | 25 | 3 | 2 | 39.4 |
| 10 | 6.96 | 4200 | 9.2 | 29 | 76 | 23 | 1 | 0 | 38.7 |
| 11 | 5.90 | 6000 | 8.9 | 26 | 66 | 33 | 1 | 0 | 39.4 |
| 14 | 6.80 | 4550 | 8.2 | 24 | 80 | 13 | 5 | 2 | 38.3 |
| 17 | 4.85 | 4600 | 8.1 | 25 | 77 | 19 | 2 | 2 | 39.4 |
| 19 | 5.73 | 4350 | 7.8 | 24 | 87 | 11 | 0 | 2 | 38.3 |
| 21 | 4.29 | 4500 | 7.2 | 22 | 80 | 19 | 0 | 1 | 38.8 |
| 24 | 3.15 | 6850 | 6.9 | 20 | 92 | 7 | 0 | 1 | 39.4 |
| 26 | 3.15 | 5750 | 6.5 | 20 | 94 | 22 | 3 | 1 | 39.3 |
| 28 | 3.27 | 8100 | 5.8 | 19 | 90 | 10 | 0 | 0 | 39.3 |
| 32 | 4.00 | 5950 | 5.7 | 18 | 77 | 21 | 2 | 0 | 39.0 |
| 34 | 4.34 | 6450 | 5.6 | 19 | 81 | 12 | 6 | 1 | 39.4 |
| 38 | 4.42 | 7350 | 5.8 | 19 | 86 | 11 | 1 | 2 | 39.6 |
| 42 | 3.80 | 4400 | 5.5 | 18 | 81 | 13 | 4 | 2 | 38.6 |
| 45 | 3.45 | 5200 | 5.5 | 17 | 74 | 25 | 1 | 0 | 38.0 |
| 48 | 3.10 | 7200 | 3.5 | 13 | 77 | 22 | 0 | 1 | 39.0 |
| 51 | 2.63 | 3950 | 4.0 | 13 | 76 | 22 | 2 | 0 | 39.0 |
| 54 | 2.52 | 6800 | 3.4 | 13 | 74 | 26 | 0 | 0 | 38.7 |
| 58 | 2.69 | 8450 | 4.0 | 13 | 81 | 10 | 0 | 0 | 38.6 |
| 60 | 2.93 | 7400 | 4.0 | 13 | 79 | 16 | 0 | 5 | 40.0 |
| 61 | 2.46 | 6250 | 4.0 | 13 | 66 | 31 | 1 | 2 | 40.0 |

Table 5 : Haematologic parameters and rectal temperatures in cow No. 26 experimentally infected with T. congolense.

| Days of Expt. | RBC x $10^6$/mm$^3$ | WBC | Hb Gm/dl | PCV % | LY % | Seg % | Eo % | Mono % | Temp. $^oC$ |
|---|---|---|---|---|---|---|---|---|---|
| -8 | 5.85 | 10350 | 10.8 | 30 | 54 | 38 | 5 | 3 | 38.6 |
| -6 | 6.30 | 5650 | 10.8 | 31 | 55 | 33 | 10 | 2 | 38.3 |
| 0 | 5.74 | 11450 | 9.8 | 30 | 68 | 23 | 9 | 0 | 38.3 |
| 3 | 6.21 | 8850 | 10.0 | 30 | 62 | 25 | 13 | 0 | 38.4 |
| 4 | 6.40 | 8500 | 9.8 | 28 | 71 | 24 | 5 | 0 | 39.1 |
| 6 | 5.36 | 7500 | 9.5 | 28 | 78 | 12 | 5 | 5 | 39.4 |
| 7 | 5.58 | 4650 | 9.1 | 27 | 64 | 28 | 8 | 0 | 39.2 |
| 8 | 6.45 | 4250 | 10.2 | 30 | 90 | 9 | 1 | 0 | 39.4 |
| 9 | 6.31 | 8000 | 10.0 | 30 | 76 | 23 | 1 | 1 | 39.8 |
| 10 | 5.40 | 4800 | 8.5 | 23 | 79 | 16 | 2 | 3 | 38.1 |
| 11 | 5.70 | 5100 | 8.8 | 25 | 82 | 16 | 2 | 0 | 38.9 |
| 14 | 5.89 | 4050 | 7.2 | 24 | 85 | 13 | 2 | 0 | 39.3 |
| 17 | 4.40 | 6850 | 7.2 | 23 | 80 | 12 | 8 | 0 | 39.0 |
| 19 | 4.05 | 4900 | 6.1 | 19 | 80 | 16 | 2 | 2 | 39.0 |
| 21 | 4.79 | 8500 | 6.5 | 19 | 69 | 19 | 11 | 1 | 39.0 |
| 24 | 3.80 | 4850 | 6.2 | 18 | 75 | 16 | 5 | 4 | 39.7 |
| 26 | 4.28 | 6650 | 5.5 | 18 | 68 | 28 | 4 | 0 | 40.0 |
| 28 | 3.67 | 5250 | 5.8 | 19 | 82 | 12 | 5 | 1 | 38.8 |
| 32 | 3.55 | 5150 | 5.0 | 15 | 70 | 15 | 4 | 1 | 38.3 |
| 34 | 3.53 | 5700 | 5.5 | 18 | 85 | 10 | 4 | 1 | 38.4 |
| 38 | 3.55 | 5050 | 5.0 | 17 | 74 | 21 | 4 | 1 | 39.0 |
| 42 | 3.17 | 4600 | 4.5 | 16 | 78 | 16 | 4 | 2 | 39.0 |
| 45 | 2.98 | 5200 | 5.0 | 16 | 71 | 23 | 4 | 2 | 38.8 |
| 48 | 2.89 | 3050 | 4.5 | 16 | 76 | 19 | 5 | 0 | 38.7 |
| 51 | 2.53 | 5050 | 4.0 | 14 | 66 | 33 | 1 | 0 | 39.3 |
| 54 | 3.04 | 5600 | 3.9 | 14 | 68 | 29 | 1 | 2 | 39.0 |
| 58 | 2.31 | 5250 | 3.7 | 13 | 77 | 20 | 1 | 2 | 38.6 |
| 60 | 1.90 | 7050 | 3.5 | 12 | 53 | 44 | 1 | 2 | 37.8 |

Table 6 : Haematologic parameters in cow No. 35 experimentally infected with T. congolense.

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | '35 | 11.6 | 8.57 | 7550 | 69 | 28 | 2 | 1 |
| 0 | 34 | 11.0 | 8.31 | 6400 | 71 | 29 | 0 | 0 |
| 4 | 35 | 11.6 | 8.96 | 6450 | 70 | 28 | 1 | 1 |
| 7 | 35 | 11.3 | 10.06 | 6150 | 72 | 24 | 2 | 2 |
| 10 | 34 | 11.3 | 8.96 | 7250 | 81 | 16 | 0 | 3 |
| 14 | 34 | 11.3 | 6.58 | 14300 | 69 | 24 | 1 | 6 |
| 17 | 33 | 10.3 | 6.43 | 11250 | 72 | 26 | 1 | 1 |
| 21 | 26 | 88.1 | 4.21 | 4950 | 88 | 11 | 1 | 0 |
| 24 | 23 | 7.3 | 4.75 | 7000 | 78 | 19 | 2 | 1 |
| 28 | 20 | 6.6 | 4.78 | 6200 | 83 | 16 | 1 | 1 |
| 31 | 20 | 6.5 | 4.82 | 8350 | 59 | 40 | 1 | 0 |
| 35 | 22 | 7.1 | 4.50 | 6050 | 77 | 20 | 3 | 0 |
| 39 | 25 | 8.3 | 5.06 | 6650 | 72 | 21 | 5 | 2 |
| 42 | 23 | 8.0 | 5.11 | 9150 | 57 | 39 | 2 | 2 |
| 45 | 25 | 8.2 | 4.65 | 9800 | 76 | 20 | 4 | 0 |
| 49 | 27 | 9.0 | 5.01 | 7400 | 70 | 26 | 4 | 0 |
| 52 | 22 | 7.0 | 5.22 | 8900 | 80 | 14 | 6 | 0 |
| 56 | 29 | 9.6 | 5.78 | 9650 | 67 | 25 | 7 | 1 |
| 59 | 29 | 9.7 | 6.07 | 9600 | 69 | 30 | 1 | 0 |
| 63 | 31 | 10.3 | 6.88 | 11350 | 60 | 39 | 0 | 1 |

Table 7 : Haematologic parameters in cow No. 36 experimentally infected with T. congolense.

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 26 | 8.6 | 7.35 | 9150 | 72 | 25 | 2 | 1 |
| 0 | 25 | 7.7 | 7.02 | 12150 | 75 | 20 | 3 | 2 |
| 4 | 26 | 8.0 | 7.45 | 11250 | 78 | 18 | 2 | 2 |
| 7 | 21 | 7.5 | 7.61 | 7150 | 81 | 16 | 2 | 1 |
| 10 | 20 | 6.3 | 4.05 | 8150 | 56 | 43 | 1 | 0 |
| 14 | 19 | 6.3 | 4.50 | 6600 | 65 | 30 | 3 | 2 |
| 17 | 16 | 5.3 | 4.54 | 6250 | 95 | 5 | 0 | 0 |
| 21 | 17 | 6.0 | 4.83 | 7100 | 90 | 10 | 0 | 0 |
| 22 | 19 | 6.0 | 4.50 | 5050 | 87 | 12 | 0 | 1 |
| 23 | 17 | 5.3 | 3.66 | 5600 | 80 | 14 | 4 | 2 |

Table 8 : Haematologic parameters in cow No. 37 experimentally infected with T. congolense.

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 36 | 12.4 | 9.08 | 10150 | 70 | 28 | 1 | 1 |
| 0 | 33 | 11.0 | 8.47 | 13750 | 62 | 33 | 5 | 0 |
| 4 | 35 | 11.6 | 7.84 | 9450 | 76 | 20 | 3 | 1 |
| 7 | 29 | 9.8 | 7.65 | 6100 | 81 | 12 | 7 | 0 |
| 10 | 26 | 8.3 | 7.35 | 7200 | 84 | 15 | 1 | 0 |
| 14 | 23 | 7.1 | 5.56 | 3150 | 85 | 13 | 2 | 0 |
| 17 | 25 | 8.0 | 6.05 | 10850 | 75 | 19 | 3 | 3 |
| 21 | 19 | 6.0 | 4.07 | 8150 | 67 | 28 | 1 | 4 |
| 24 | 18 | 5.4 | 4.78 | 6650 | 61 | 22 | 14 | 3 |
| 28 | 17 | 4.6 | 3.34 | 6950 | 77 | 20 | 2 | 1 |
| 31 | 21 | 7.0 | 3.59 | 5350 | 68 | 21 | 9 | 2 |
| 35 | 19 | 5.5 | 3.37 | 7200 | 71 | 23 | 5 | 1 |
| 39 | 19 | 6.2 | 3.02 | 6150 | 91 | 8 | 1 | 0 |
| 42 | 17 | 6.3 | 2.69 | 3450 | 68 | 28 | 2 | 3 |
| 45 | 15 | 5.5 | 2.40 | 5200 | 85 | 10 | 2 | 3 |
| 49 | 15 | 5.0 | 2.36 | 4400 | 82 | 16 | 1 | 1 |
| 52 | 15 | 4.5 | 2.08 | 3600 | 86 | 13 | 1 | 0 |
| 56 | 16 | 5.4 | 2.32 | 4750 | 88 | 10 | 2 | 0 |
| 59 | 14 | 4.0 | 2.33 | 5250 | 76 | 22 | 2 | 0 |
| 63 | 16 | 4.7 | 3.13 | 3800 | 77 | 19 | 2 | 2 |

Table 9 : Haematologic parameters in cow No. 38 experimentally infected with T. congolense.

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 28 | 8.8 | 5.81 | 13250 | 49 | 48 | 2 | 1 |
| 0 | 28 | 8.6 | 5.45 | 12150 | 51 | 45 | 33 | 1 |
| 4 | 30 | 10.5 | 5.85 | 11250 | 56 | 38 | 4 | 2 |
| 7 | 28 | 9.0 | 6.02 | 12500 | 46 | 48 | 55 | 1 |
| 10 | 28 | 9.0 | 6.02 | 12500 | 56 | 36 | 6 | 2 |
| 14 | 26 | 8.3 | 5.81 | 6750 | 43 | 40 | 13 | 4 |
| 17 | 25 | 8.3 | 5.36 | 9500 | 67 | 25 | 2 | 6 |
| 21 | 21 | 6.3 | 4.53 | 14100 | 66 | 28 | 2 | 6 |
| 24 | 19 | 6.0 | 4.30 | 11550 | 72 | 20 | 3 | 5 |
| 28 | 19 | 5.4 | 4.88 | 11150 | 63 | 34 | 1 | 2 |
| 31 | 19 | 6.6 | 3.49 | 11200 | 58 | 33 | 7 | 2 |
| 35 | 21 | 6.7 | 3.64 | 9850 | 70 | 22 | 8 | 0 |
| 39 | 20 | 7.0 | 3.82 | 14800 | 73 | 23 | 4 | 0 |
| 42 | 21 | 7.0 | 3.29 | 16600 | 72 | 23 | 5 | 0 |
| 45 | 22 | 7.5 | 3.21 | 11450 | 62 | 35 | 3 | 0 |
| 49 | 20 | 6.6 | 3.15 | 9250 | 59 | 39 | 2 | 0 |
| 52 | 21 | 6.0 | 3.54 | 10700 | 55 | 41 | 4 | 0 |
| 56 | 21 | 6.6 | 3.83 | 8550 | 63 | 25 | 9 | 3 |
| 59 | 21 | 6.4 | 4.21 | 17350 | 62 | 29 | 7 | 2 |
| 63 | 21 | 6.6 | 3.56 | 11800 | 65 | 28 | 7 | 0 |

Table 10: Haematologic parameters in cow No. 39 experimentally infected with *T. congolense*

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 28 | 9.0 | 6.07 | 12150 | 60 | 35 | 3 | 2 |
| 0 | 29 | 9.6 | 6.88 | 11850 | 57 | 34 | 9 | 0 |
| 4 | 28 | 9.7 | 6.05 | 8250 | 66 | 31 | 2 | 1 |
| 7 | 27 | 9.0 | 7.56 | 6100 | 71 | 11 | 14 | 4 |
| 10 | 24 | 7.7 | 6.35 | 7250 | 66 | 33 | 1 | 0 |
| 14 | 24 | 8.0 | 4.78 | 9850 | 56 | 40 | 1 | 3 |
| 17 | 24 | 8.0 | 4.65 | 9900 | 86 | 10 | 3 | 1 |
| 21 | 19 | 6.8 | 4.11 | 6450 | 71 | 26 | 1 | 2 |
| 24 | 17 | 5.4 | 3.48 | 5450 | 68 | 28 | 1 | 3 |
| 28 | 20 | 6.6 | 3.12 | 13400 | 78 | 16 | 6 | 0 |
| 31 | 22 | 7.1 | 4.64 | 12700 | 72 | 12 | 10 | 6 |
| 35 | 20 | 6.6 | 3.98 | 12700 | 67 | 25 | 6 | 2 |
| 39 | 19 | 6.0 | 3.13 | 11050 | 73 | 15 | 12 | 0 |
| 42 | 19 | 6.6 | 4.11 | 12200 | 68 | 11 | 1 | 0 |
| 45 | 22 | 7.0 | 3.63 | 9450 | 84 | 12 | 3 | 1 |
| 49 | 17 | 5.7 | 3.71 | 6650 | 98 | 17 | 4 | 1 |
| 52 | 16 | 4.8 | 2.84 | 9250 | 62 | 28 | 6 | 4 |
| 56 | 19 | 6.0 | 4.78 | 8550 | 62 | 26 | 11 | 1 |
| 59 | 17 | 5.3 | 3.26 | 12250 | 62 | 32 | 5 | 1 |
| 63 | 17 | 5.5 | 3.60 | 11000 | 73 | 18 | 6 | 3 |

Table 11 : Haematologic parameters in control cow No. 40

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 27 | 8.6 | 6.12 | 8000 | 56 | 18 | 25 | 1 |
| 0 | 26 | 8.7 | 7.0 | 9250 | 58 | 20 | 2 | 2 |
| 4 | 26 | 8.7 | 6.07 | 8150 | 60 | 20 | 18 | 2 |
| 7 | 27 | 9.2 | 7.95 | 9100 | 58 | 16 | 25 | 1 |
| 10 | 28 | 9.0 | 7.36 | 11250 | 57 | 23 | 20 | 0 |
| 14 | 27 | 9.0 | 6.98 | 15500 | 52 | 37 | 9 | 2 |
| 17 | 26 | 8.3 | 5.13 | 15500 | 45 | 18 | 35 | 2 |
| 21 | 24 | 6.6 | 4.17 | 11500 | 58 | 34 | 5 | 3 |
| 24 | 24 | 6.6 | 5.40 | 7750 | 49 | 29 | 17 | 5 |
| 28 | 28 | 9.4 | 4.30 | 11650 | 42 | 46 | 11 | 1 |
| 31 | 29 | 9.5 | 5.23 | 13750 | 60 | 19 | 17 | 4 |
| 35 | 27 | 8.7 | 5.21 | 14750 | 42 | 35 | 5 | 1 |
| 39 | 29 | 9.8 | 5.60 | 21600 | 52 | 34 | 2 | 2 |
| 42 | 31 | 10.0 | 5.62 | 15150 | 62 | 26 | 1 | 1 |
| 45 | 29 | 9.0 | 5.09 | 11800 | 55 | 31 | 14 | 0 |
| 49 | 28 | 9.3 | 6.82 | 14800 | 67 | 19 | 12 | 2 |
| 52 | 26 | 8.3 | 4.13 | 13200 | 67 | 21 | 12 | 0 |
| 56 | 29 | 9.3 | 5.69 | 16350 | 57 | 22 | 20 | 1 |
| 59 | 28 | 9.3 | 6.67 | 26900 | 42 | 50 | 8 | 0 |
| 63 | 29 | 9.7 | 7.18 | 20000 | 57 | 13 | 0 | 0 |

Table 12: Haematologic parameters in control cow No. 41

| Days of Expt. | PCV % | Hb Gm/dl | RBC x $10^6$/mm$^3$ | WBC | LY % | Seg % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -1 | 29 | 9.6 | 6.84 | 5550 | 66 | 30 | 4 | 0 |
| 0 | 28 | 9.2 | 6.25 | 9150 | 70 | 20 | 8 | 2 |
| 4 | 27 | 8.9 | 5.86 | 8150 | 71 | 12 | 13 | 0 |
| 7 | 28 | 9.0 | 6.57 | 8150 | 71 | 12 | 13 | 4 |
| 10 | 31 | 11.0 | 6.35 | 9250 | 65 | 32 | 2 | 1 |
| 14 | 31 | 10.6 | 6.84 | 9900 | 47 | 45 | 6 | 2 |
| 17 | 28 | 9.6 | 6.25 | 11650 | 58 | 40 | 1 | 2 |
| 21 | 29 | 9.9 | 6.83 | 9550 | 52 | 39 | 4 | 5 |
| 24 | 27 | 9.0 | 5.21 | 6850 | 84 | 15 | 0 | 1 |
| 28 | 28 | 9.0 | 4.69 | 9400 | 65 | 31 | 1 | 3 |
| 31 | 29 | 9.6 | 5.01 | 10950 | 69 | 22 | 4 | 5 |
| 35 | 28 | 9.6 | 4.14 | 10250 | 75 | 19 | 5 | 1 |
| 39 | 30 | 10.2 | 6.93 | 13250 | 73 | 25 | 1 | 1 |
| 42 | 29 | 9.6 | 6.10 | 11650 | 65 | 30 | 3 | 2 |
| 45 | 29 | 9.5 | 6.15 | 9850 | 70 | 26 | 3 | 1 |
| 49 | 29 | 10.2 | 6.06 | 12750 | 72 | 21 | 5 | 2 |
| 52 | 26 | 8.7 | 5.24 | 12700 | 70 | 26 | 3 | 1 |
| 56 | 30 | 10.3 | 6.40 | 11650 | 76 | 17 | 3 | 4 |
| 59 | 30 | 9.7 | 8.85 | 20750 | 59 | 32 | 6 | 3 |
| 63 | 31 | 11.0 | 9.28 | 20450 | 71 | 25 | 4 | 0 |

Table 13 : PI, UIBC, TIBC and SC in cow No. 22 experimentally infected with T. congolense.

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 95 | 105 | 200 | 47.5 |
| -2 | 94 | 115 | 209 | 44.9 |
| 0 | 115 | 75 | 190 | 60.5 |
| 3 | 135 | 90 | 225 | 60.0 |
| 6 | 88 | 125 | 213 | 41.3 |
| 7 | 60 | 130 | 190 | 31.6 |
| 9 | 70 | 135 | 205 | 34.1 |
| 10 | 125 | 35 | 160 | 78.1 |
| 11 | 125 | 60 | 185 | 67.5 |
| 14 | 110 | 70 | 180 | 61.1 |
| 19 | 90 | 75 | 165 | 54.5 |
| 21 | 88 | 90 | 178 | 49.4 |
| 24 | 75 | 90 | 165 | 45.5 |
| 26 | 95 | 80 | 175 | 54.3 |
| 28 | 108 | 140 | 248 | 43.5 |
| 32 | 95 | 95 | 190 | 50.0 |
| 34 | 108 | 100 | 208 | 51.9 |
| 38 | 70 | 135 | 205 | 34.1 |
| 45 | 95 | 105 | 200 | 47.5 |
| 48 | 200 | 85 | 285 | 70.2 |
| 51 | 125 | 138 | 263 | 47.5 |
| 54 | 185 | 100 | 285 | 64.9 |
| 58 | 180 | 22 | 202 | 89.1 |
| 60 | 168 | 30 | 198 | 84.8 |

Table 14: PI, UIBC, TIBC and SC in cow No. 23 experimentally infected with T. congolense.

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 52 | 83 | 135 | 38.5 |
| -2 | 50 | 130 | 180 | 27.7 |
| 0 | 75 | 105 | 180 | 41.7 |
| 4 | 70 | 75 | 145 | 48.3 |
| 6 | 40 | 102 | 142 | 28.2 |
| 8 | 55 | 50 | 105 | 52.3 |
| 9 | 88 | 73 | 161 | 54.7 |
| 10 | 115 | 40 | 155 | 74.2 |
| 11 | 50 | 85 | 135 | 37.0 |
| 14 | 83 | 0 | 83 | 100.0 |
| 17 | 72 | 65 | 137 | 52.6 |
| 19 | 67 | 50 | 135 | 49.6 |
| 21 | 72 | 65 | 137 | 52.6 |
| 24 | 78 | 50 | 128 | 60.9 |
| 26 | 86 | 135 | 220 | 38.6 |
| 28 | 110 | 60 | 170 | 64.7 |
| 32 | 90 | 70 | 160 | 56.3 |
| 38 | 106 | 55 | 161 | 65.8 |
| 42 | 48 | 115 | 163 | 29.4 |
| 45 | 150 | 75 | 225 | 66.6 |
| 48 | 110 | 95 | 205 | 53.6 |
| 51 | 110 | 94 | 204 | 53.9 |
| 54 | 146 | 0 | 146 | 100.0 |
| 58 | 136 | 0 | 136 | 100.0 |
| 60 | 90 | 15 | 105 | 85.7 |
| 61 | 130 | 30 | 160 | 81.2 |

Table 15 : PI, UIBC, TIBC and SC in cow No. 24 experimentally infected with T. congolense.

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 110 | 200 | 310 | 35.4 |
| -2 | 105 | 190 | 295 | 35.5 |
| 0 | 100 | 115 | 215 | 46.5 |
| 3 | 70 | 95 | 165 | 42.4 |
| 6 | 78 | 140 | 218 | 35.7 |
| 10 | 20 | 130 | 150 | 13.3 |
| 11 | 22 | 135 | 157 | 14.0 |
| 14 | 55 | 120 | 175 | 31.4 |
| 17 | 100 | 105 | 205 | 48.8 |
| 19 | 105 | 105 | 210 | 50.0 |
| 21 | 120 | 120 | 240 | 50.0 |
| 24 | 142 | 110 | 252 | 56.3 |
| 26 | 70 | 100 | 170 | 41.2 |
| 28 | 45 | 120 | 165 | 27.3 |
| 32 | 95 | 240 | 335 | 21.8 |
| 34 | 80 | 115 | 195 | 41.0 |
| 38 | 104 | 135 | 239 | 43.5 |
| 42 | 65 | 125 | 190 | 34.2 |
| 45 | 48 | 200 | 248 | 19.3 |
| 48 | 85 | 235 | 320 | 26.5 |
| 51 | 98 | 210 | 308 | 31.8 |
| 54 | 80 | 115 | 195 | 41.0 |
| 58 | 55 | 100 | 155 | 35.5 |
| 60 | 55 | 100 | 155 | 35.5 |
| 61 | 145 | 80 | 225 | 64.4 |

Table 16: PI, UIBC, TIBC, and SC in cow No. 25 experimentally infected with T. concolense.

| Days of Expt. | P I ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 84 | 120 | 204 | 41.2 |
| -2 | 125 | 112 | 237 | 52.7 |
| 0 | 105 | 110 | 215 | 48.8 |
| 3 | 90 | 115 | 205 | 43.9 |
| 6 | 60 | 132 | 192 | 31.2 |
| 7 | 45 | 150 | 195 | 23.1 |
| 9 | 38 | 180 | 218 | 17.4 |
| 10 | 72 | 110 | 182 | 39.5 |
| 11 | 65 | 100 | 165 | 39.5 |
| 14 | 72 | 90 | 162 | 44.4 |
| 17 | 95 | 80 | 175 | 54.3 |
| 19 | 125 | 65 | 190 | 65.7 |
| 21 | 92 | 95 | 187 | 48.2 |
| 24 | 60 | 120 | 180 | 33.3 |
| 26 | 92 | 110 | 202 | 45.5 |
| 28 | 100 | 210 | 310 | 32.2 |
| 32 | 95 | 115 | 210 | 57.1 |
| 38 | 98 | 140 | 238 | 41.1 |
| 42 | 132 | 60 | 192 | 68.7 |
| 45 | 84 | 155 | 239 | 35.1 |
| 48 | 280 | 90 | 270 | 75.6 |
| 51 | 130 | 225 | 355 | 36.6 |
| 54 | 162 | 15 | 177 | 91.5 |
| 58 | 110 | 85 | 195 | 56.4 |
| 60 | 84 | 62 | 146 | 57.5 |

Table 17: PI, UIBC, TIBC and SC in cow No. 26 experimentally infected with *T. congolense*.

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 73 | 110 | 183 | 39.8 |
| -2 | 60 | 150 | 210 | 28.5 |
| 0 | 60 | 75 | 135 | 44.4 |
| 3 | 62 | 90 | 152 | 40.8 |
| 6 | 30 | 160 | 190 | 15.8 |
| 7 | 20 | 145 | 165 | 12.1 |
| 9 | 35 | 160 | 195 | 17.9 |
| 10 | 30 | 110 | 140 | 21.4 |
| 11 | 92 | 70 | 162 | 56.8 |
| 14 | 106 | 80 | 186 | 56.9 |
| 17 | 70 | 95 | 165 | 42.4 |
| 19 | 85 | 75 | 160 | 53.1 |
| 21 | 86 | 85 | 171 | 50.3 |
| 24 | 65 | 110 | 175 | 37.1 |
| 26 | 70 | 115 | 185 | 37.8 |
| 28 | 80 | 170 | 250 | 32.0 |
| 32 | 80 | 120 | 200 | 40.0 |
| 34 | 67 | 130 | 197 | 34.0 |
| 38 | 65 | 135 | 200 | 32.5 |
| 42 | 92 | 135 | 227 | 40.5 |
| 45 | 60 | 280 | 340 | 13.6 |
| 48 | 68 | 145 | 213 | 31.9 |
| 51 | 126 | 120 | 246 | 51.2 |
| 54 | 98 | 50 | 148 | 66.2 |
| 58 | 165 | 0 | 165 | 100.0 |
| 60 | 112 | 15 | 127 | 88.1 |

Table 18: PI, UIBC, TIBC and SC in cow No. 35 experimentally infected with T. congolense

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 100.0 | 67.5 | 167.5 | 59.7 |
| -1 | 100.0 | 140.0 | 240.0 | 41.7 |
| 0 | 100.0 | 140.0 | 240.0 | 41.7 |
| 4 | 90.0 | 117.5 | 207.5 | 43.4 |
| 7 | 92.5 | 157.5 | 230.0 | 40.2 |
| 10 | 85.0 | 120.0 | 205.0 | 41.5 |
| 14 | 106.5 | 80.0 | 186.5 | 57.1 |
| 17 | 135.0 | 44.0 | 179.0 | 75.4 |
| 21 | 122.5 | 94.0 | 216.5 | 56.6 |
| 24 | 100.0 | 67.5 | 167.5 | 59.7 |
| 28 | 117.5 | 94.0 | 211.5 | 55.6 |
| 31 | 106.5 | 157.5 | 264.0 | 40.3 |
| 35 | 112.5 | 200.0 | 312.5 | 36.0 |
| 39 | 127.5 | 157.5 | 285.0 | 44.7 |
| 42 | 62.5 | 140.0 | 202.5 | 30.9 |
| 45 | 68.5 | 157.0 | 226.0 | 30.3 |
| 49 | 77.5 | 127.5 | 205.0 | 37.8 |
| 52 | 122.0 | 100.0 | 194.0 | 48.5 |
| 56 | 145.0 | 127.5 | 272.5 | 53.2 |
| 59 | 213.0 | 200.0 | 413.0 | 51.6 |
| 63 | 162.5 | 170.0 | 332.5 | 48.9 |

Table 19 : PI, UIBC, TIBC and SC in cow No. 36 experimentally infected with T. congolense

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 62.0 | 140.0 | 202.0 | 30.7 |
| -1 | 62.5 | 67.5 | 130.0 | 36.2 |
| 4 | 62.5 | 117.5 | 180.0 | 34.7 |
| 7 | 55.0 | 100.0 | 155.0 | 35.5 |
| 10 | 100.0 | 80.0 | 180.0 | 55.6 |
| 14 | 72.5 | 117.5 | 190.0 | 38.2 |
| 17 | 50.0 | 80.0 | 130.0 | 38.5 |
| 21 | 68.5 | 50.0 | 118.5 | 57.8 |
| 22 | 72.5 | 50.0 | 122.5 | 59.2 |

Table 20: PI, UIBC, TIBC and SC in cow No. 37 experimentally infected with T. congolense

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 145.0 | 127.5 | 272.5 | 53.2 |
| -1 | 90.0 | 140.0 | 230.0 | 39.1 |
| 0 | 122.5 | 150.0 | 272.5 | 44.9 |
| 4 | 112.5 | 100.0 | 212.5 | 32.9 |
| 7 | 137.5 | 44.0 | 181.5 | 75.8 |
| 10 | 122.5 | 140.0 | 265.5 | 46.1 |
| 14 | 72.5 | 117.5 | 190.0 | 38.2 |
| 17 | 145.0 | 107.5 | 252.5 | 57.4 |
| 21 | 127.5 | 127.5 | 255.0 | 50.0 |
| 24 | 122.5 | 44.0 | 166.0 | 73.6 |
| 28 | 120.0 | 100.0 | 220.0 | 54.6 |
| 31 | 225.0 | 50.0 | 275.0 | 81.8 |
| 35 | 92.5 | 94.0 | 187.5 | 49.3 |
| 39 | 112.5 | 94.0 | 206.5 | 54.5 |
| 42 | 112.5 | 180.0 | 292.5 | 38.5 |
| 45 | 155.0 | 67.5 | 222.5 | 69.7 |
| 49 | 135.0 | 100.0 | 235.0 | 57.5 |
| 52 | 122.5 | 117.5 | 240.0 | 51.0 |
| 56 | 145.0 | 80.0 | 225.0 | 64.4 |
| 59 | 213.0 | 80.0 | 293.0 | 65.7 |
| 63 | 122.5 | 107.5 | 230.0 | 53.3 |

Table 21: PI, UIBC, TIBC and SC in cow No. 38 experimentally infected with T. congolense

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 90.0 | 80.0 | 170.0 | 52.9 |
| -1 | 92.5 | 127.5 | 220.0 | 42.1 |
| 0 | 127.5 | 117.5 | 245.0 | 52.0 |
| 4 | 155.0 | 117.5 | 272.5 | 56.9 |
| 7 | 155.0 | 100.0 | 255.0 | 50.8 |
| 10 | 100.0 | 140.0 | 240.0 | 41.7 |
| 14 | 92.5 | 117.5 | 210.0 | 44.1 |
| 17 | 100.0 | 127.5 | 227.5 | 43.9 |
| 21 | 112.5 | 117.5 | 230.0 | 48.9 |
| 24 | 127.5 | 44.0 | 171.5 | 74.3 |
| 28 | 122.5 | 44.0 | 166.5 | 73.6 |
| 31 | 122.5 | 80.0 | 202.5 | 60.5 |
| 35 | 117.5 | 57.5 | 175.0 | 67.1 |
| 39 | 106.5 | 117.5 | 224.0 | 47.5 |
| 42 | 127.5 | 80.0 | 207.5 | 61.5 |
| 45 | 135.0 | 117.5 | 252.5 | 53.5 |
| 49 | 122.5 | 80.0 | 202.5 | 60.5 |
| 52 | 100.0 | 67.5 | 167.5 | 59.7 |
| 56 | 145.0 | 100.0 | 245.0 | 59.2 |
| 59 | 122.5 | 157.5 | 280.0 | 43.7 |
| 63 | 205.0 | 100.0 | 305.0 | 57.2 |

Table 22: PI, UIBC, TIBC and SC in cow No. 39 experimentally infected with T. congolense

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 122.5 | 67.5 | 190.0 | 64.5 |
| -1 | 127.5 | 117.5 | 245.0 | 52.0 |
| 0 | 92.5 | 94.0 | 186.5 | 49.6 |
| 4 | 122.5 | 100.0 | 222.5 | 55.1 |
| 7 | 76.0 | 140.0 | 216.0 | 35.2 |
| 10 | 77.5 | 94.0 | 171.5 | 45.2 |
| 14 | 68.5 | 100.0 | 168.5 | 40.7 |
| 17 | 85.0 | 117.5 | 202.5 | 41.9 |
| 21 | 72.5 | 127.5 | 200.0 | 36.3 |
| 24 | 90.0 | 44.0 | 134.0 | 67.2 |
| 28 | 122.5 | 57.5 | 180.0 | 68.9 |
| 31 | 135.0 | 50.0 | 185.0 | 72.9 |
| 35 | 72.5 | 150.0 | 222.5 | 32.6 |
| 39 | 112.5 | 100.0 | 212.5 | 53.9 |
| 42 | 76.0 | 127.5 | 203.5 | 37.4 |
| 45 | 135.0 | 44.0 | 179.0 | 75.4 |
| 49 | 106.5 | 107.5 | 214.0 | 49.8 |
| 52 | 90.0 | 120.0 | 210.0 | 43.9 |
| 56 | 112.5 | 150.0 | 262.5 | 42.9 |
| 59 | 76.0 | 200.0 | 276.0 | 27.5 |
| 63 | 150.0 | 100.0 | 250.0 | 60.0 |

Table 23 : PI, UIBC, TIBC and SC in control cow No. 40

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 135.0 | 94.0 | 229.0 | 58.9 |
| -1 | 150.0 | 57.5 | 207.5 | 72.3 |
| 0 | 145.0 | 67.5 | 212.5 | 68.2 |
| 4 | 135.0 | 57.5 | 192.5 | 70.2 |
| 7 | 85.0 | 107.5 | 192.5 | 44.2 |
| 10 | 135.0 | 57.5 | 192.5 | 70.1 |
| 14 | 92.5 | 94.0 | 186.5 | 49.6 |
| 17 | 106.5 | 57.5 | 164.0 | 64.9 |
| 21 | 135.0 | 67.5 | 202.5 | 66.7 |
| 24 | 135.0 | 94.0 | 229.0 | 58.9 |
| 28 | 145.0 | 44.0 | 189.0 | 76.7 |
| 31 | 135.0 | 107.5 | 242.5 | 55.7 |
| 35 | 90.0 | 157.5 | 247.5 | 36.4 |
| 39 | 137.5 | 127.5 | 265.0 | 51.9 |
| 42 | 72.5 | 94.0 | 166.5 | 43.5 |
| 45 | 122.5 | 80.0 | 202.5 | 60.5 |
| 49 | 137.5 | 100.0 | 237.5 | 57.9 |
| 52 | 127.5 | 50.0 | 177.5 | 71.8 |
| 56 | 145.0 | 80.0 | 225.0 | 64.4 |
| 59 | 112.5 | 170.0 | 282.5 | 39.8 |
| 63 | 155.0 | 100.0 | 255.0 | 60.8 |

Table 24: PI, UIBC, TIBC and SC in control cow No. 41

| Days of Expt. | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -4 | 106.5 | 100.0 | 206.5 | 51.6 |
| -1 | 112.5 | 57.5 | 170.0 | 66.2 |
| 0 | 106.5 | 94.0 | 100.5 | 53.1 |
| 4 | 112.5 | 100.0 | 212.5 | 52.9 |
| 7 | 100.0 | 67.5 | 167.5 | 59.7 |
| 10 | 112.5 | 150.0 | 262.5 | 42.9 |
| 14 | 72.5 | 200.0 | 272.5 | 26.6 |
| 17 | 92.5 | 107.5 | 200.0 | 46.3 |
| 21 | 122.5 | 94.0 | 216.5 | 56.6 |
| 24 | 122.5 | 44.0 | 166.5 | 73.6 |
| 28 | 135.0 | 100.0 | 235.0 | 57.5 |
| 31 | 135.0 | 127.5 | 262.5 | 51.4 |
| 35 | 85.0 | 157.5 | 242.5 | 35.1 |
| 39 | 137.5 | 127.5 | 265.0 | 51.9 |
| 42 | 112.5 | 94.0 | 206.5 | 54.5 |
| 45 | 145.0 | 140.0 | 285.0 | 50.9 |
| 49 | 155.0 | 117.5 | 232.5 | 66.7 |
| 52 | 145.0 | 57.5 | 202.5 | 71.6 |
| 56 | 170.0 | 57.5 | 227.5 | 74.8 |
| 59 | 213.0 | 157.5 | 370.5 | 57.5 |
| 63 | 185.0 | 67.5 | 252.5 | 73.7 |

# APPENDIX 7: HAEMATOLOGY, FI, UIBC, TIBC AND SC IN 2 CONTROL COWS

Table 1 : Haematologic parameters in control cow No. 33

| Days of Expt | PCV % | Hb gm/dl | RBC x $10^6/m^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 37 | 11.5 | 8.95 | 10550 | 41 | 51 | 0 | 8 |
| -1 | 32 | 10.3 | 8.37 | 6550 | 72 | 21 | 3 | 4 |
| 0 | 30 | 9.5 | 7.03 | 7950 | 63 | 33 | 2 | 2 |
| 3 | 32 | 10.7 | 8.03 | 11250 | 52 | 42 | 5 | 1 |
| 6 | 36 | 12.1 | 6.88 | 12500 | 43 | 53 | 0 | 4 |
| 9 | 34 | 11.0 | 8.46 | 9850 | 68 | 31 | 0 | 1 |
| 12 | 36 | 11.7 | 8.41 | 10650 | 54 | 39 | 0 | 7 |
| 15 | 32 | 10.7 | 8.14 | 12100 | 73 | 25 | 1 | 1 |
| 18 | 31 | 10.1 | 8.87 | 14300 | 76 | 19 | 3 | 2 |
| 21 | 28 | 9.7 | 6.34 | 13600 | 83 | 17 | 0 | 0 |
| 23 | 30 | 9.7 | 7.12 | 10750 | 72 | 24 | 0 | 4 |
| 26 | 33 | 10.6 | 8.34 | 11250 | 61 | 37 | 1 | 1 |
| 28 | 31 | 10.0 | 7.13 | 12500 | 67 | 29 | 2 | 2 |
| 30 | 30 | 10.0 | 6.78 | 18650 | 64 | 34 | 2 | 0 |
| 32 | 33 | 10.7 | 7.27 | 19250 | 73 | 24 | 0 | 3 |
| 35 | 32 | 10.2 | - | - | - | - | - | - |
| 39 | 30 | 9.6 | 10.31 | 19650 | 66 | 30 | 1 | 3 |
| 42 | 32. | 10.3 | - | - | - | - | - | - |
| 46 | 35 | 11.3 | 7.62 | 17650 | 74 | 25 | 0 | 1 |
| 49 | 32 | 11.1 | 7.89 | 16500 | 60 | 38 | 0 | 2 |
| 51 | 32 | 10.3 | - | - | - | - | - | - |
| 54 | 37 | 12.3 | 9.87 | 10750 | 74 | 19 | 1 | 6 |
| 56 | 37 | 12.3 | 8.02 | 11750 | 62 | 29 | 4 | 5 |
| 58 | 38 | 12.5 | - | - | - | - | - | - |
| 61 | 39 | 13.3 | 10.40 | 12350 | 64 | 35 | 1 | 0 |
| 63 | 38 | 12.2 | - | - | - | - | - | - |

Table 2 : Haematologic parameters in control cow No. 34

| Days of Expt. | PCV % | Hb gm/dl | RBC x $10^6$/$mm^3$ | WBC | LY % | Neut % | Eo % | Mono % |
|---|---|---|---|---|---|---|---|---|
| -3 | 36 | 11.6 | 7.35 | 13400 | 68 | 28 | 0 | 4 |
| -1 | 35 | 11.3 | 6.79 | 6700 | 70 | 30 | 0 | 0 |
| 0 | 30 | 9.5 | 7.25 | 10250 | 76 | 19 | 0 | 5 |
| 3 | 32 | 10.7 | 6.17 | 8600 | 46 | 50 | 1 | 3 |
| 6 | 35 | 11.5 | 7.25 | 7200 | 52 | 48 | 0 | 0 |
| 9 | 32 | 10.3 | 8.48 | 5000 | 56 | 38 | 2 | 4 |
| 12 | 31 | 10.4 | 8.02 | 8750 | 59 | 39 | 1 | 1 |
| 15 | 32 | 10.3 | 8.37 | 8250 | 36 | 62 | 0 | 2 |
| 18 | 30 | 9.6 | 6.97 | 6550 | 50 | 49 | 1 | 0 |
| 21 | 29 | 9.7 | 8.49 | 10200 | 58 | 42 | 0 | 0 |
| 25 | 31 | 10.1 | 7.15 | 9750 | 44 | 55 | 0 | 1 |
| 28 | 29 | 9.0 | 6.81 | 9200 | 56 | 43 | 1 | 0 |
| 32 | 33 | 10.7 | 9.20 | 13400 | 48 | 47 | 2 | 3 |
| 34 | 33 | 11.5 | 8.74 | 9150 | 55 | 43 | 0 | 2 |
| 39 | 34 | 11.3 | 8.94 | 10500 | 57 | 43 | 0 | 0 |
| 42 | 34 | 11.0 | - | - | - | - | - | - |
| 46 | 34 | 11.2 | 10.60 | 13900 | 60 | 40 | 0 | 0 |
| 49 | 32 | 10.9 | - | - | - | - | - | - |
| 51 | 32 | 11.0 | - | - | - | - | -- | - |
| 54 | 31 | 10.9 | 8.97 | 7250 | 70 | 28 | 0 | 2 |
| 56 | 31 | 10.6 | 6.63 | 6500 | 54 | 42 | 0 | 4 |
| 58 | 36 | 12.0 | - | - | - | - | - | - |
| 61 | 36 | 12.5 | 8.84 | 16200 | 83 | 15 | 1 | 1 |
| 63 | 33 | 10.2 | - | - | - | - | - | - |

Table 3 : PI, UIBC, TIBC and SC in control cow 33

| Days of Expt | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 120.0 | 100.0 | 220.0 | 54.6 |
| 0 | 112.5 | 94.0 | 206.5 | 54.5 |
| 3 | 127.5 | 67.5 | 195.0 | 65.4 |
| 7 | 137.5 | 50.0 | 187.5 | 73.3 |
| 11 | 122.5 | 50.0 | 172.5 | 71.0 |
| 13 | 112.5 | 80.5 | 193.0 | 58.3 |
| 16 | 117.5 | 57.5 | 174.5 | 67.3 |
| 20 | 145.0 | 57.5 | 202.5 | 71.6 |
| 25 | 162.5 | 57.5 | 220.0 | 73.9 |
| 29 | 122.5 | 100.0 | 222.5 | 55.1 |
| 34 | 122.5 | 80.0 | 202.5 | 60.6 |
| 37 | 122.5 | 100.0 | 222.5 | 55.1 |
| 42 | 137.5 | 117.5 | 255.0 | 53.9 |
| 46 | 100.0 | 107.5 | 207.5 | 48.2 |
| 49 | 127.5 | 94.0 | 221.5 | 57.6 |
| 53 | 122.5 | 67.5 | 190.0 | 64.5 |
| 55 | 106.0 | 100.0 | 206.0 | 51.5 |
| 61 | 122.5 | 94.0 | 216.5 | 56.6 |
| 63 | 100.0 | 67.5 | 167.5 | 59.7 |

Table 4 : PI, UIBC, TIBC and SC in control cow 34.

| Days of Expt | PI ug/dl | UIBC ug/dl | TIBC ug/dl | SC |
|---|---|---|---|---|
| -1 | 100.0 | 94.0 | 194.0 | 51.6 |
| 0 | 85.0 | 100.0 | 185.0 | 45.9 |
| 3 | 85.0 | 140.0 | 225.0 | 37.8 |
| 7 | 100.0 | 20.0 | 120.0 | 83.3 |
| 11 | 100.0 | 44.0 | 144.0 | 69.4 |
| 13 | 122.5 | 157.5 | 280.0 | 43.8 |
| 16 | 135.0 | 67.5 | 202.5 | 66.7 |
| 20 | 106.5 | 44.0 | 150.5 | 70.8 |
| 25 | 150.0 | 57.5 | 207.5 | 72.3 |
| 29 | 145.0 | 50.0 | 190.0 | 76.3 |
| 34 | 155.0 | 80.0 | 235.0 | 65.9 |
| 37 | 122.5 | 117.5 | 240.0 | 51.0 |
| 42 | 155.0 | 117.5 | 272.5 | 56.9 |
| 46 | 122.5 | 100.0 | 222.5 | 55.1 |
| 49 | 135.0 | 67.5 | 202.5 | 66.7 |
| 53 | 122.5 | 117.5 | 240.0 | 51.0 |
| 55 | 135.0 | 117.5 | 252.5 | 53.5 |
| 61 | 135.0 | 57.5 | 192.5 | 70.1 |
| 63 | 106.5 | 80.0 | 185.5 | 57.1 |

# HAEMATOLOGY, SERUM IRON AND IRON-BINDING CAPACITY IN APPARENTLY NORMAL AND TRYPANOSOME INFECTED ZEBU CATTLE

by

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It is widely recognized that per capita consumption of animal protein by the average Nigerian is below acceptable standards. Inadequate animal nutrition and disease have contributed immensely to the limited availability of animal protein at prices that the average Nigerian can afford. The government has embarked on programmes of accelerated livestock production in a bid to increase animal protein.

Trypanosomiasis has long been the major disease of Nigerian livestock. Management and treatment of trypanosomiasis depends, at least in part, upon an understanding of the pathogenesis of the disease. It was to gain further insight into the pathogenesis of trypanosomiasis that this study was undertaken.

Since information on baseline haematologic and biochemical parameters in Nigerian cattle was not available, it was necessary to establish normal values in both local and exotic breeds of cattle in Nigeria. Baseline haematologic and chemical parameters were established in three categories of cattle viz:

1. Zebu cattle under improved husbandry and management practices.
2. Zebu cattle under semi-improved management practices.

3. Zebu cattle under nomadic husbandry practices.

Cattle under improved husbandry and management practices had blood values nearer those found in cattle elsewhere than did the latter two groups. Zebu cattle under nomadic husbandry practices had the lowest haematologic values while those on semi-improved husbandry and management practices occupied an intermediate position. Exotic cattle raised in the tropics under improved management practices had haematologic values that compared favourably with their counterparts elsewhere.

Investigations on the mechanisms involved in the development of anaemia in bovine trypanosomiasis centred on the evaluation of changes in haematologic parameters, erythrocyte morphologic changes, histologic changes in reticuloendothelial organs viz bone marrow, spleen, lymph nodes, kidney and liver. The changes in serum iron and iron-binding capacity in infected cattle were also evaluated.

The disease produced in cattle by all strains of trypanosomes used was essentially chronic. The most constant finding was the development of anaemia. Based on peripheral blood morphologic response and bone marrow cytology, it was concluded that the anaemia developed as

a result of accelerated erythrocyte destruction. Histologic and bone marrow cytologic findings indicated that the reticuloendothelial organs were the primary site of erythrocyte destruction. Factors which predisposed the erythrocytes to the accelerated destruction were not determined. It was further concluded from serum iron studies that the development of anaemia in trypanosomiasis was not associated with iron-deficiency. The absence of protracted hyperferremia suggested that intravascular haemolysis was not an important factor.

Suggestions were made for further studies on various aspects of the development of anaemia in trypanosomiasis.

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Suggestions were made for further studies on various aspects of the development of anaemia in trypanosomiasis.