A STUDY OF SOME ENVIRONMENTAL EFFECTS ON THE PHYSIOLOGY OF JERSEY AND FRIESIAN CATTLE IN THE LAKE CRESCENT AREA OF UGANDA

by

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DECLARATION

I declare that this thesis has not been submitted for a degree in any other University. All work contained herein is original unless otherwise stated.

R. G. Packham.

R. G. PACKHAM

6th June, 1969.

To my Father, Mother and Wife, Donna

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CONTENTS

SUMMARY

It is hypothesised that Bos taurus breeds of dairy cattle are subjected to stress, either directly or indirectly, by the environment of the Lake Crescent region of Uganda. The response to this stress is examined by observing its effect on some blood constituents.

The examination of the data produced the following results:

(a) The definition of the usual values for some blood constituents of Jersey and Friesian cows in the Lake Crescent region.

(b) The haemoglobin and packed cell volume levels of the Jersey animal at 10.6 gms % and 31.6% respectively were lower than published results for known temperature conditions. The corresponding Friesian results, 12.1 gms % and 34.6%, were in better agreement, though still on the low side. The values for the total erythrocyte count of both Jersey and Friesian animals were in good agreement with published results from England.

The total leucocyte counts of the Jersey and Friesian animals were in agreement with some published results from England, but above others. On examining the differential leucocyte count, it was noted that the lymphocyte count of 6.423 thou/ml for the Jerseys and 4.456 thou/ml for the Friesians was higher than the published figures for known temperature conditions,

while the neutrophil count was lower for both the Jersey (1.928 thou/ml) and Friesian (1.892 thou/ml) animals. With both breeds the eosinophil count agreed with the published results. From these findings, it was concluded that a breed difference existed between the Jersey and Friesian animals for some of the blood factors.

(c) The various blood factors all appeared to have a reasonably normal distribution, though a skew to the left was noted in most cases, except for the packed cell volume and total erythrocyte count which both had a slight skew to the right.

The daily variation for the various blood parameters was calculated and 95% confidence limits of the variation presented for an individual observation and the means of a series of observation.

(d) The blood picture of Jersey animals probably changes with age.

(e) The origin of the animal, whether from a tropical or temperate environment, has no apparent effect on the erythrocyte picture. With the leucocyte picture however, there was a considerable effect of origin. A general increase in all aspects of the leucocyte picture was noted for the cows recently imported from England, as compared to those bred locally.

(f) The main effect of climate and of milk production was on the haemoglobin and packed cell volume results. Maximum and minimum

temperatures and milk production seemed to be exerting the main effect on these blood factors, with sun hours having a lesser effect on haemoglobin levels. Multiple linear regression equations are given, significant at greater than the 1% level, for these relationships. When there were high maximum and low minimum temperatures, the haemoglobin levels were high. At these times the milk production was low, this possibly being due to high temperatures causing a decrease in the metabolic processes of milk production to ensure the cows had adequate reserves to withstand stress.

The effect of the climate and milk production on the leucocyte picture appeared from the results to be minimal. However, there may have been an effect, and this might have been obscured by a high infection rate of disease organisms.

(g) There was shown to exist an interaction between pregnancy and lactation, acting on the haemoglobin values, the packed cell volume results, and the total neutrophil counts. In these interactions there was little difference between the lactating and non-lactating animals during pregnancy but a large difference was noted in the non-pregnant condition. The lactating animals had lower haemoglobin and packed cell volume results, but higher neutrophil counts than the non-lactating animals.

The eosinophil count showed a main effect of pregnancy, and

no interaction with lactation. This count increased during the early stages of pregnancy, returning to normal levels during the latter part.

(h) The changes in the blood factors recorded for the Danish Friesian in-calf heifers (KDF) on introduction to the environment of the Lake Crescent region were different from those noted for the Danish Friesian calves (EDF). These variations have been described.

Future investigations into the production records of the two groups may indicate if these different responses of the blood factors are due to an increased adaptability on the part of the in-calf heifers as compared to the calves, or vice-versa.

(i) The results of the KDF heifers and EDF calves showed considerable differences from the results obtained for the Kabanyolo cows (KKF) which had been bred locally. This seemed to indicate that, as in the case of the Jersey animals, the new environment was causing changes in the blood picture of the newly arrived cattle.

(j) The measurement of stress via the blood picture, and the association of milk production and the blood picture are discussed.

(1) INTRODUCTION

A STUDY OF SOME ENVIRONMENTAL EFFECTS ON THE PHYSIOLOGY OF JERSEY AND FRIESIAN CATTLE IN THE LAKE CRESCENT AREA OF UGANDA

(1) INTRODUCTION

Many areas of Uganda are very suitable for milk production. Through most of the year the forage is conducive to milk production, but despite this the average production from Bos taurus dairy breeds is considerably below that of similar animals in temperate zones. It is hypothesized in this thesis that the quality of the grasses and forages and the climate produce physiological stress which decreases milk production.

The total milk output in Uganda for human consumption was estimated at 79 million gallons in 1963 (F.A.O., 1967). Only about five per cent was marketed in urban areas, though attempts are being made to improve upon this level. Thus there was a shortage of supply in these areas which had to be met by imports from Kenya. Uganda's Second Five-Year Plan (1966) included the objective to increase milk production by twenty-five per cent by 1971. This could be done by importing high quality European breeds, by cross-breeding and up-grading local cattle, and through better animal husbandry and management techniques.

There is an acute shortage of Bos taurus dairy breeds in East Africa, so the importation of animals can only make a minor contribution to the planned increase in milk production, as little capital is available to finance large-scale importations. Thus, any way of increasing milk production by reducing physiological stress produced by the tropical climate and forages would make a significant contribution to the economy and welfare of East Africa.

It has been stated that Bos taurus dairy breeds were only able to acclimatize where the mean annual temperature did not exceed 65°-70°F (18.3°-21.1°C) (Wright, 1946) and, prior to 1961, there were no significant importations of these animals into Uganda (F.A.O., 1967). The Government tried to improve milk production by upgrading the local indigenous Zebu breeds (Bos indicus). Experimental data became available which showed that, with the increasing demand for milk, the Nganda, a local indigenous Zebu breed, would never be able to supply the needs of Uganda. It was decided to experiment with the introduction of more highly productive Bos taurus dairy animals. Jerseys were the first animals brought in and their immediate success led to further importations of Jersey, Friesian and Ayrshire cattle.

Brody (1956) indicated the 'comfort' zone for Bos taurus animals as 35°-70°F (1.7°-21.1°C). Above 70°F (21.1°C) he

showed that milk production began to decline, but the production was vastly superior to that found in Uganda for the pure Nganda. For most of the year the area under study experiences temperatures at or above the upper limit of this zone. Thus it was possible for animals in this area to be subjected to a climatic stress, which, were it eased in some way, could lead to increased milk production. It was hoped that some measure of stress could be evaluated in this paper.

The 'average' Bos taurus dairy cow in this region is said to produce in the range of 500-700 gallons of milk (2273-3183 litres) (F.A.O., 1967), though this figure may be an over-estimation. The Jersey occupies the lower end of the scale and the Friesian the upper but, since the fat-content is considerably higher in Jersey milk, the 4% F.C.M. production is about the same for both breeds. It is worth noting here that in Uganda, as the situation stands, there is no incentive paid for high-fat milk and therefore the Friesian is becoming more popular than the Jersey. This level of production for both breeds however is considerably lower than the average production of similar cows in temperate countries. While much of the blame for this may be due to poorer management, a considerable portion might be due to the effects of the environment. This could be direct stress on the animal and by indirect environmental effects on fodder crops or other causes.

In the present study the effect of the environment was examined as it affected some blood constituents. An attempt was made to correlate these with some aspects of production.

From the results it may be possible to recommend changes in management practices which would reduce stress and thereby possibly increase production. It may also be possible to develop indices of adaptation and selection for breeding for milk production. This last aim is not of particular importance at present, where a large increase in numbers of cows is required, but will gain importance as the volume of milk produced begins to meet the present very large demand.

(2) OBJECTIVES

2. OBJECTIVES

a) Determine the usual haematological values of Jersey and Friesian cattle in the Lake Crescent region of Uganda.

b) Determine if these values are significantly different from those obtained for similar animals in temperate environments.

c) Determine if the origin of a Bos taurus animal has any effect on its blood picture.

d) Determine the effects of the climate on the blood picture throughout the year, and try to determine the most important elements of the climate with regard to these effects.

e) Determine the effects of pregnancy and lactation on the blood picture.

f) Determine the response to a change from a temperate to a tropical environment in the blood picture of Friesian calves and heifers.

g) Attempt to find indices to measure physiological stress as it occurs in this area.

h) Try to correlate changes in the blood picture with some aspects of production.

(3) REVIEW OF LITERATURE

REVIEW OF LITERATURE

The problems of heat tolerance have been studied intensively in the last twenty years due to the importation of Bos taurus breeds of cattle from temperate zones into the tropics in an attempt to improve human nutrition. Work has been done, both in the field and in climate laboratories, to determine the physiological effects of a tropical environment. Bianca (1965) reviewed the whole field of the physiological effects caused by a hot environment on cattle. Other reviews by Hancock (1954) and Rice (1965) examine the influence of a hot environment on milk production itself.

The physiology of an animal may be affected by the environment both directly and indirectly. The most important direct effects are considered by Hancock (1954) to be air temperature, solar radiation temperature, humidity (relative and absolute) and air-flow. Bianca (1965) confirms this view, but qualifies the effect of air-flow as being important only when environmental temperatures exceed body temperatures. Wright (1946) attempted to combine some of these variables into a 'climograph' but no wholly satisfactory measurement, combining all or several climatic factors into one unit, has yet been discovered.

In the tropics the most acute problem for the animal is to

keep its body temperature from rising beyond physiological limits. Reviews by Lee and Phillips (1948), Lee (1949), Findlay (1950) and Patchell (1951), and the various bulletins presenting the work of the Missouri School, notably Blincoe and Brody (1951), Brody (1948; 1949), Kibler and Brody (1949; 1950a; 1950b; 1951), Kibler et al (1949), Ragsdale et al (1948; 1949; 1950; 1951), Stewart et al (1951), Thompson et al (1949a; 1949b; 1951a; 1951b; 1952), and the papers by Bonsma (1949), Dowling (1956), Johnston et al (1958), Robinson and Klem (1953), Klem and Robinson (1955) and Bianca (1959a; 1959b), all investigate the problem of the mechanism of temperature regulation. Basically it may be summarised by the equation

$$M - E \pm F \pm Cd \pm Cv \pm R = 0$$ (Williamson and Payne, 1959),

where M is the metabolic heat production, E the heat loss from the skin and respiratory passage by evaporation, F the heat lost or gained bringing ingested food or water to body temperature, Cd heat lost or gained by direct contacts between the skin and surrounding surfaces, Cv heat lost or gained by convection and R heat lost or gained by radiation. Metabolic heat production will depend on (i) level of food intake, (ii) type of food and (iii) the catabolic or anabolic processes for which the nutrients are used.

To counteract the effects of rising body temperature, the animal can seek shade, relax, vasodilate, avoid unnecessary exercise, decrease feed intake, decrease hair thickness and length, increase respiration rate, and increase vaporization from the respiratory tract and the skin by a combination of one or more of these. The effect of a high environmental temperature on actual metabolic heat production depends on the way the heat stress is applied (Bianca, 1965). If it is an acute stress, metabolic heat production rises; if it is a chronic effect, the heat production over a period of time will tend to fall (Kibler, 1960; Kibler and Brody, 1949).

These thermoregulatory mechanisms, particularly the effect of lowering feed intake and a lower basal metabolism, have the effect of lowering milk production. Temperatures in the range of 40°-70°F (2°-21°C) have no influence on milk yield, but above 70°F milk yield decreases, slowly at first with a sudden drop occurring at 80°F (Ragsdale et al, 1948, 1949, 1950, 1951). This fall is thought to be due to decrease feed intake, support for this view coming from the work of Regan and Richardson (1938). Reproductive ability is also impaired. Stott and Williams (1962) obtained evidence that high temperatures lowered the rate of fertilization in Holstein cows, and cows of British breeds in South Africa produced calves in summer that

were 20% lighter than winter-born calves (Bonsma, 1948).

Work done on the environmental effects on cattle in climatic chambers, however, tends to show only short-term effects, rather than the long term effects, which may tend to be different and to which the animals are subjected in Uganda.

Despite the adverse effect of a tropical environment, Bos taurus dairy breeds of cattle still have a better production record under these conditions than indigenous breeds. Also, Bos taurus dairy breeds have a far better potential for milk production, since their production in temperate conditions is considerably higher. Thus, ways of alleviating heat stress in a practical manner must be sought after, in an effort to allow European-type animals to attain their full potential.

Before such methods can be evaluated, however, the degree of heat stress has to be determined, so that the effects of a particular method of alleviating heat stress can be evaluated. Rhoad (1944) developed the Iberia heat tolerance test for cattle. Lee and Phillips (1948) published a laboratory analogue to this test (R-values), based on measurements of rectal temperature under standardized hot conditions. A comprehensive publication by Lee (1953) deals with these and various other methods of estimating heat tolerance. Yeates (1956), Turner (1958) and Bianca (1961) have all published papers discussing heat tolerance in cattle.

The present thesis will deal mainly with the investigation of the more direct effects of climate. It will be concerned with the changes in the blood picture caused by these effects. The role played by the blood and its circulation in the heat-stressed animal is most complex. Bianca (1965) points out that haematological changes may indicate mobilization of defence and establishment of new equilibria, as well as breakdown of body functions and deterioration. Findlay (1950) discusses the effects of climate on the blood picture in more detail, and mentions that it may be possible to use haemoglobin levels as an indicie of heat tolerance. This view received support from Rusoff, Frye and Scott (1951), but little more seems to have been done on this subject since then. Findlay (1954) states that sudden falls in temperature cause rises in the leucocyte count of the blood of cattle from temperate regions, possibly due to new types of infection attacking the body, but no work appears to have been carried out on the effects of tropical environments on the leucocyte picture.

The basic premise used for this thesis is that if increased heat loads imposed on an animal of temperate origin by a tropical environment cause a stress reaction, this should be apparent from a study of the blood picture. Selye (1950) in his book on stress describes the body reactions that occur. He describes the sum of all non-specific systemic reactions of

the body which ensue upon long-continued exposure to systemic stress, as the General Adaption Syndrome (G-A-S). This is composed of three stages (a) the alarm-reaction (b) the stage of resistance and (c) the stage of exhaustion, which occurs when adaption to prolonged over-exposure to a stimulus has been developed, but cannot be maintained. He states that temperature has an important influence on the course of the G-A-S and can itself act as a potent systemic stress.

The alarm-reaction of the G-A-S is characterised in the haematological responses of neutrophilia, lymphopenia and eosinopenia. If the stress is very severe, haemoconcentration will ensue, with the haematocrite and erythrocyte count rising above normal. The neutrophilia aids in defence against the stress through phagocytosis of invading disease organisms, while the lymphopenia and eosinopenia result from the increased use of these cells, since they contain substances useful for humoral defence. The erythrocytosis may represent an excessive defence measure to furnish adequate oxygen carriers for the increased metabolic needs of an emergency.

The haematologic response that results from a stress reaction will depend largely upon the proportion of adrenegic and glucocorticoid hormones discharged, as well as upon the responsiveness of the whole blood-cell system. Thompson et al

(1963) have investigated the effects of a hot environment on adrenal, cortical, thyroidal and other metabolic responses. Both the production of adrenal hormones and the responsiveness of the peripheral target organs (circulating or stored blood cells, haemopoietic and blood-destroying tissues) depend very considerably upon conditioning factors such as heredity, nutrition, specific actions of the stressor and so on. It is mainly due to such differences in conditioning that, through the same mechanisms, exposure to stress can produce varying haematologic changes under different circumstances.

The procedures used to measure the various blood parameters are described by Dacie and Lewis (1963) and these have been followed in this thesis and are described in section (4). The methods used in blood analysis can affect the readings obtained. Packed Cell Volume values are particularly susceptible, Greatorex (1957) stating that these depend on the type of anti-coagulant used. Reeve (1948) quotes a figure of 4-5% as being the amount of plasma trapped within the cells after certifuging the haematocrite sample, this referring to the conventional-speed machines. With the micro-haematocrite method, as used in this thesis, Garby and Vuille (1961) quote a much lower figure of 1.1 - 1.5% trapped plasma and, since this figure is fairly constant, it is rarely corrected. Dacie and Lewis (1963) give

estimates of the inherent error of the total erythrocyte count. They show how accuracy increases with the number of cells counted. The coefficient of variation for the numbers counted in this paper is about 4.3%, and that for the white cell count is between 5 - 10%. The differential white cell count is subject to considerably more errors and, to achieve a reasonable degree of accuracy, films must be spread evenly.

The normal values in the blood morphology of the cow, and the various factors affecting these values, have been extensively reviewed by Schalm (1965).

A point worth stressing at this stage is that most work has been done on the blood picture of the cow as a pre-requisite for determining disease states. Thus quoted figures are intended to give normal values and ranges, beyond which the animal can be said to be ill. Only a few workers have studied the blood picture with the aim of determining seasonal or climatic variations within this normal range, such as Braun (1946) and Greatorex (1957).

Results of the blood values of cattle from England have been published by Holman (1955; 1956) and Greatorex (1954; 1957). These authors discuss results obtained for calves, heifers and adult animals. They also discuss the effects of various influences, such as age, breed, environment, pregnancy and parturition, and lactation on the blood picture. Holman

(1955) discusses the daily variation that might be expected within various haematological factors and presents 95% confidence limits for this daily variation. He also discusses the distribution of the various readings for the blood factors. Holman used eighty-one Ayrshire cows, all over three years of age. Greatorex (1957) used two hundred and thirty-three calves and forty-nine adult cows representing each of the five main dairy breeds of Great Britain - Shorthorns, Guernseys, Friesians, Ayrshires and Jerseys. Both authors bring out several interesting points; care must be taken when bleeding cows to avoid over-excitement, since this can alter the various blood values very rapidly due to a stress reaction. Gartner et al (1965) studied the influence of the degree of excitation and showed statistically significant differences between animals at rest and animals that were excited. Holman and Greatorex both stress the effect of age on the blood picture, a fact that is supported by several other workers. Greatorex (1957) also mentions that a breed difference seems to occur, and quotes an overall mean, and also a mean for the Jersey animals, that is considerably lower.

Very few results have been published for work done on blood values of cattle in the tropics; even fewer results are available for work done in Africa. Symington (1965) and Walker (1958) give results from Central Africa, Canham (1930) has published

figures for South Africa, and Lampkin and Howard (1962) for East Africa. Much of this work, however, refers to indigenous types of cattle and not to the superior dairy animals of European origin.

Many results are available from America, notably papers by Bell and Irwin (1938); Benjamin (1953); Braun (1946); Brody (1949); Delaune (1939); Ferguson, Irwin and Beach (1945); Moore (1946); Neal and Becker (1933); Reid, Ward and Salsbury (1948); and Schalm (1965). Other results have been published by Albritton (1958); Allcroft (1941); Byers et al (1952); Dale, Burge and Brody (1956); Dalton and Fisher (1961); Fraser (1929); Gartner et al (1965); Gonzaga (1939); Gourlay (1959); and Rusoff, Frye and Scott (1951).

(4) MATERIALS AND METHODS

(4) MATERIALS AND METHODS

(a) The Animals

(i) Jerseys

Twenty Jersey cows which belonged to the dairy herd of the Livestock Experimental Husbandry Unit, Nakyesasa, were used in the experiment. Ten were from a group of twenty-two home-bred animals and ten came from a group of one hundred and forty-eight imported English animals. These animals were imported in April 1967 as 'served' or in-calf heifers. They formed part of a shipment of 316 Friesian and Jersey cattle imported by the Ministry of Animal Industry, Game and Fisheries under Project 19 of the U.K./Uganda Loan No.2, 1966. The animals were generally of superior quality, as shown by an analysis of their pedigrees (Redfern, 1967). The two groups of Jerseys were designated 'JV' for home-bred and 'JE' for imported English stock. Also at Nakyesasa were 'JA' - imported American stock - and 'JG' - imported Kenyan stock, with twenty animals in each group. These initials were given to the classes of animals to aid in the data processing of their various records. They fit in to the code suitable for use with an I.C.T. computer (Redfern, 1968).

The animals required for the experiment were selected by a simple procedure. First, of the twenty-two JV animals, three were barren, one had just aborted, and one was in its third

lactation. This left seventeen animals that were normal and healthy and were comparable with the JE animals. The ten required were drawn randomly from all the numbers placed in a hat. The JE cows were then paired off against these selected JV animals using the following criteria, in order of preference:

1. Next calving date,
2. Previous calving date,
3. Age,
4. Milk yield,
5. Weight.

Where two or more cows seemed equally suitable, a choice was made by drawing numbers randomly from a hat.

As with any experiment with breeding cows, no control could be applied to ensure the animals became pregnant when bred. Thus, at the end of three months work, the pairs were re-examined and three of the JE and one JV cows were replaced, since their expected calving dates no longer matched their partners.

The JA and JG animals were older animals, run in the same herd. Ten of each of these two groups were also selected, by simply drawing numbers from a hat. With these it was hoped that some conclusions could be drawn regarding the effect on the blood picture of the length of time an animal has been subjected

to a tropical environment. All the animals had been in Uganda for at least three years, some for considerably longer.

(ii) Friesians

Forty Friesian animals were used in the experiment. These were imported into Uganda in August 1968. They were flown direct from Denmark and were made up of sixteen calves and twenty-four in-calf heifers. The calves went to the FAO Dairy Training School in Entebbe, while the heifers were sent to the University Farm, Kabanyolo. There were no abortions during or soon after the flight and, except for one animal which calved a month early, all began calving at term from November 1968 onwards. The University Farm already had some Friesian animals of various ages, all originating from Kenyan stock. Ten of these were selected at random, and were incorporated at the end of the experiment to give an indication of normal blood values for established Friesian animals.

(b) Description of Area

The area in which the study took place lies just north of the equator between latitudes 0° 32'N and 0° 10'N, longitude 32° 37'E. Kabanyolo and Nakyesasa are 3,766 ft above sea level,

Entebbe is slightly lower at 3,655 ft. All three stations fall into the area of Uganda known as the Lake Crescent region. The whole of this area consists of a dissected peneplain, with flat-topped hills capped by a protective layer of laterite, and separated by deep valleys. The bottoms of these valleys are generally swampy but the valley sides are quite fertile. The general agriculture of the region is basically a subsistence agriculture, with cash cropping of coffee and cotton in the available remaining land. The staple food crop is matoke bananas but maize, cassava and other food crops are also grown.

(c) The Climate of the Area

The area under study had an equatorial-type climate. This was characterized by a double maxima of temperature and rainfall, these being controlled by the annual march of the sun. Temperatures were, comparatively speaking, uniformly high throughout the year, remaining around the 70°F (21°C) mark. The mean annual range was quite small, at about 3°F, while the thermometer rarely rose above 95°F (35°C), or fell below 60°F (15.5°C).

Season was determined by rainfall in the absence of any marked temperature change. The principal rains were of the conventional type and reached a maximum shortly after the

passage of the Zenithal sun, about April, and November. The April maxima was greater than that for November. The rainfall was generally high and reliable at approximately fifty inches a year.

Details of the monthly mean climatic figures are given in Appendix 3.

(d) Feeding and Management

(i) Nakyesasa

The Unit was founded and still functions to act as a stock multiplication unit and to upgrade the local Nganda cattle by crossbreeding with Jerseys. The Unit had a stocking rate of about two beasts per acre on the productive grassland around the dairy where all the milking animals were kept. During the experiment there was no grass shortage, even in the dry season. The animals were run for about two days on a five-acre paddock, then moved to another five-acre paddock, and the rotation continued. Dry and pregnant animals were kept in a separate herd from the milkers but the management was basically the same. The milking animals were fed concentrates at the rate of five lbs per gallon of milk produced, although recently this has been shown to be overfeeding. Now maintenance plus the first gallon comes from the grass and concentrate was only fed above this, at

the rate of 5 lbs per gallon of milk. The concentrate composition was 70.2% starch equivalent and 14.1% protein equivalent. The pastures consist mainly of Chloris gayana, with some Brachiaria ruziziensis, Setaria sphecelata and Panicum maximum. There was no significant legume contribution from the pasture.

The Unit aimed to breed a heifer at 16-18 months or 600 lb weight. Cows were inseminated at the first heat after eight weeks from calving. However, since their condition was not good after a long sea voyage (Redfern, 1967), the JE animals had a fifteen-month calving interval prior to their second lactation (Sserwadda, 1968). The cows were milked twice a day at 3 a.m. and 3 p.m. The average daily production of the herd was between 1 and 2 gallons at about 5.1% butterfat. The figures for 1968 are shown in Table 1.

TABLE 1 Lactation Records for JE and JV Cows *

Group	Lactation	Mean Yield (lb)	Butter Fat %	Mean Length (days)
Jersey home-bred (JV)	2nd	4517	5.1	331
Jersey England (JE)	1st	4274	5.1	373

* Adapted from Sserwadda (1968)

Finally, as a protection against East Coast Fever, the whole farm was surrounded by a double fence with a ploughed furrow separating the two, and all the cattle on the farm were sprayed with toxaphene twice a week.

(ii) Kabanyolo

Kabanyolo Farm was the farm of Makerere University College and was run by the Faculty of Agriculture. The farm consisted of 340 acres of land, of which 290 were developed. It was run as a mixed farm since one aspect of farm policy was to develop an economic integration of crops and animals in the tropical environment of the Lake Crescent area. Herd management was similar to that at Nakyesasa.

(iii) Entebbe

The Danish calves were imported to form the basis of a dairy herd on the planned pilot/teaching dairy farm for the FAO dairy training and demonstration course for English-speaking countries in Africa. The land was recently acquired from the Veterinary Training Institute, Entebbe. As the land had yet to be fully developed and no dairy unit had been built, the calves were not allowed to run with the Friesian bull which had been imported with them, even though some were of breeding age and size. The

land had been sown chiefly with Panicum maximum. In addition to this grazing, the calves received some supplementary concentrates.

The calves were sprayed twice weekly as at Nakyesasa and Kabanyolo.

(e) Sampling and Measurement of Blood and Blood Values

(i) Blood sampling

All samples were taken by venepuncture from apparently healthy animals: if any animal showed disease symptoms, it was excluded until it recovered. Care was taken to avoid any undue distress to the animal as far as possible. Two 4 ml samples of blood were taken from the jugular vein at each bleeding using 2" 17 gauge veterinary needles. All samples were taken between 8 a.m. and 9 a.m. except for the Entebbe calves which, by necessity, were bled between 4 p.m. and 5 p.m.

(ii) Anticoagulant

Both samples of blood were collected in 5 ml glass, screw-topped bottles containing dried Disodium sequentrene (E.D.T.A.). To make the anticoagulant a 10% (w/v) solution was made up in distilled water and four drops from a Pasteur pipette - capable of delivering about 50 drops per ml - were delivered into the

bottles as described by Dacie and Lewis (1963). The bottles were dried in a cool oven. Care had to be taken that the blood and coagulant were thoroughly mixed together, by repeated gentle inversions of the container for about a minute after the withdrawal of the blood sample.

(iii) Estimation of Blood Values

The methods used were those described by Dacie and Lewis (1963).

Haemoglobin Estimation: The Cyanmethaemoglobin method was used. Two hundredths of a millilitre of blood were added to 4 ml of modified Drabkin's cyanide ferricyanide solution, prepared as follows:

KCN	0.2 gms
$K_3Fe(CN)_6$	0.2 gms
$NaHCO_3$	1.0 gms
Distilled Water	1 litre

The mixture was left for three to four minutes. After this time the gms % of haemoglobin were read directly with an EEL colourimeter, which was standardized using known dilutions containing 5 gms % and 15 gms % haemoglobin. The samples were done in duplicate.

The Packed Cell Volume: The micro-haematocrite method was employed. Commercially available unheparanized micro-haematocrite tubes were used, one end being sealed in a bunsen flame after filling the tube by capillary action about three quarters full with blood. The tubes were spun in a high-speed Hawksley micro-haematocrite centrifuge for four minutes. The machine provided a centrifugal force of about 12,000 g. Dacie and Lewis (1963), quoting Garby and Vuille (1961) estimate the amount of trapped plasma at 1.1 - 1.5% (mean 1.3%). The percentage of cells was read off after spinning using a special scale, which compensates for variation in the amount of blood filling the haematocrite tubes. The buffy coat layer was not included in the reading. The samples were done in duplicate.

The Erythrocyte Count: Erthrocyte counts were made by diluting 0.02 ml of blood with 4 mls of a solution of 3% sodium citrate to which 1% formalin had been added. Dilutions were made in bulk in a 5 ml screw-top bottle using a 0.02 ml blood pipette. A haemocytometer with Improved Neubauer rulings was used counting five large squares, or a total of eighty small squares. Two counts were made from two separate dilutions and any difference of 10% or more (approximately 50 cells) necessitated a recount. To obtain the erythrocyte numbers per ml the mean of the two actual counts was multiplied by 10,000.

The Leucocyte Count: 0.05 ml of blood were diluted with 0.95 ml of dilutant. The diluting fluid was a 2% aqueous solution (v/v) of acetic acid coloured pale violet with gentian violet. The dilutions were again done in bulk in 5 ml bottles, this time using a 0.05 ml blood pipette. The same haemocytometer was used as in the erythrocyte count, but only large squares were counted around the edge of the central area of small squares. Four groups of sixteen of these large squares were counted, giving a total of sixty-four squares. Again two counts were made on two separate dilutions and any error above 10% necessitated a recount. To give the total number per ml, the mean of the two actual counts was multiplied by 50.

The Differential Counts: Films were prepared from the blood samples as soon as possible after their collection. They were fixed for three minutes in methyl alcohol and then treated with Giemsa Stain for 45-60 minutes. The stain was used at a dilution of 1:50, Giemsa:Distilled water. At least 200 cells were counted straight across the slide approximately in the centre of the smear.

(f) Statistics

Monthly means of the measured blood factors were recorded for the various groups of animals, together with overall means and associated standard deviations and standard errors. A 24-hour

variation study was made on the Jerseys and, from these results, 95% confidence limits for the mean were calculated. This daily variation is made up of both errors in the methods of estimation and variation due to individuals and short-term environmental effects.

If the differences of two monthly means exceed these 95% confidence intervals, it would tend to indicate that a real difference did exist and the results could not be explained on the basis of an inherent day-to-day variability.

Analysis of variance was done on the JE and JV animals to indicate any differences between the two groups and also any effect of pregnancy and lactation. Also, an attempt was made, using multiple regression, to define changes in blood factors by changes in climatic factors or milk production.

With the Friesians an attempt was made to define changes in blood factors from month to month after their arrival, and to compare these with their values in Denmark prior to their departure. Both these results were compared with Normal values for Friesians at Kabanyolo.

The Statistical methods used in this thesis are described by Steel and Torrie (1960). They include a 2" factorial design, a 2" factorial design with unequal sub-class numbers, and multiple linear regression analysis. These techniques were carried out in

part on an electric Facit calculator, and in part on an IBM 360 series 30 32 K-byte computer. The computer programmes were written in FØRTRAN, and the data punched on cards.

(5) THE NORMAL BLOOD PICTURE

(5) THE NORMAL BLOOD PICTURE

The objective of this chapter is to define the normal values of the various blood factors investigated. Since a total of 240 readings were made for each of the seven blood factors concerning the Jersey animals, these results can be discussed with reasonable confidence. However, the only results that are suitable from the Friesian data are those of the ten animals sampled from the rest of the Kabanyolo herd. The Danish Friesian results, both from Kabanyolo and Entebbe cannot be used except as an indication of normal values, since their results show considerable change on their introduction to a new environment. Apart from examining normal values, the distribution of these values will be examined, and the possible daily variation of the blood factors defined.

Results for the mean values, together with their standard deviations and standard errors, of the various blood factors investigated are presented in Tables 2 and 3. Where a statistical difference was shown between the JE and JV groups (see Chapter 6), means are given for both these groups as well as the overall mean. Comparisons of these results with other workers' results are made difficult due to the fact that most other work has been done on several breeds of animals, and the overall mean alone has been published. Other methods of analysis have also

TABLE 2 Average Values of some Blood Constituents of Jersey Cows in Uganda

TEST		GROUP: Jersey	Jersey daily variation
		n = 20 (10/10) r = 12	n = 10 r = 1
Hb. gms %		10.57 ± 1.04 s.e. = 0.33	10.97 ± 0.53 s.e. = 0.17
P.C.V. %		31.56 ± 2.46 s.e. = 0.78	31.42 ± 2.42 s.e. = 0.76
R.B.C. mill/ml		5.570 ± 0.585 s.e. = 0.185	5.303 ± 0.628 s.e. = 0.199
W.B.C. thou/ml	JE JV ALL	10.348 ± 1.812 9.092 ± 2.064 9.720 ± 2.039 s.e. = 0.425	9.836 ± 1.120 s.e. = 0.354
Lymphocytes thou/ml (%)*	JE JV ALL	6.732 ± 1.294(65.3)* 6.113 ± 1.596(67.1)* 6.423 ± 1.483(66.2)* s.e. = 0.309	6.714 ± 0.732 (68.7)* s.e. = 0.231
Neutrophils thou/ml (%)*	JE JV ALL	2.155 ± 0.929(20.7)* 1.701 ± 0.658(18.5)* 1.928 ± 0.835(19.6)* s.e. = 0.174	1.839 ± 0.786 (18.5)* s.e. = 0.249
Eosinophils thou/ml (%)*	JE JV ALL	1.228 ± 0.580(11.9)* 1.077 ± 0.424(12.1)* 1.153 ± 0.512(12.0)* s.e. = 0.107	1.282 ± 0.386 (12.7)* s.e. = 0.122

s.e. = $\frac{s.d.}{\sqrt{n}}$; n = number in sample ; r = replicates

TABLE 3 Average values of some blood constituents of Friesian cattle in Uganda

TEST	GROUP				
	Kabanyolo	Danish Heifers	Danish Heifers†	Entebbe Calves	Entebbe Calves†
	n = 10 r = 1	n = 24 r = 6	n = 24 r = 1	n = 16 r = 5	n = 16 r = 1
Haemoglobin gms %	12.1 ± 0.82 s.e. = 0.26	11.92 ± 1.02 s.e. = 0.21	12.64 ± 1.11 s.e. = 0.23	11.1 ± 0.94 s.e. = 0.24	11.84 ± 0.89 s.e. = 0.22
P.C.V. %	34.6 ± 2.76 s.e. = 0.50	36.13 ± 2.44 s.e. = 0.75	37.58 ± 3.69 s.e. = 0.75	33.72 ± 2.72 s.e. = 0.68	37.06 ± 2.77 s.e. = 0.69
R.B.C. mill/ml	5.537 ± 0.525 s.e. = 0.166	6.211 ± 0.568 s.e. = 0.116	6.537 ± 0.793 s.e. = 0.162	7.047 ± 0.688 s.e. = 0.172	6.322 ± 0.965 s.e. = 0.241
W.B.C. thou/ml	7.195 ± 1.367 s.e. = 0.397	8.712 ± 1.943 s.e. = 0.408	7.254 ± 1.999 s.e. = 0.432	9.994 ± 2.636 s.e. = 0.659	9.325 ± 2.781 s.e. = 0.695
Lymphocytes thou/ml (%)*	4.456 ± 0.789 (62.5)* s.e. = 0.250	5.737 ± 1.756 (64.6)* s.e. = 0.366	9.996 ± 1.059 (57.0)* s.e. = 0.221	6.765 ± 1.835 (67.0)* s.e. = 0.459	5.771 ± 1.791 (62.3)* s.e. = 0.448
Neutrophils thou/ml (%)*	1.892 ± 0.639 (25.7)* s.e. = 0.202	2.185 ± 1.121 (24.1)* s.e. = 0.262	2.587 ± 1.412 (33.9)* s.e. = 0.294	2.524 ± 1.396 (24.8)* s.e. = 0.349	3.278 ± 1.405 (34.6)* s.e. = 0.351
Eosinophils thou/ml (%)*	0.848 ± 0.356 (11.8)* s.e. = 0.113	0.730 ± 0.451 (8.5)* s.e. = 0.094	0.670 ± 0.354 (9.1)* s.e. = 0.074	0.535 ± 0.434 (5.1)* s.e. = 0.108	0.274 ± 0.218 (3.1)* s.e. = 0.054

† = sampled in Denmark s.e. = $\frac{s.d.}{\sqrt{n}}$; n = number in sample ; r = replicates

* = to value of the differential count

often been used, and so conclusions as to the effect of environment being the cause of any differences must, of necessity, be reserved.

A summary of published results from England is given in Table 4. While there are a considerable number of published results regarding blood values, it was thought for our purposes that most of these were not comparable. The data from America did not list climatic conditions but came from areas in which there were high temperatures at some times of the year. While some data has been presented from environmental laboratories the experimental periods were too short for comparable results. The English results came from animals kept for long periods in a known cool environment.

(a) The erythrocyte picture - The haemoglobin level of the Jersey animals, at 10.57, was lower than that given by most other workers. 11.0 - 11.5 appears to be the accepted mean in England (Holman, 1955; Greatorex, 1957). The Friesian cows showed a closer agreement with some of the published figures, notably those of Greatorex (1957) in England. The mean of 12.1 is, however, higher than Holman (1955) found.

The Packed Cell Volume mean of 31.6% for the Jersey animals is similarly lower than the findings of other workers in temperate conditions. The Friesian mean of 34.6 is in much

TABLE 4 Some Published Results of Blood Values from England

Reference	Greatorex (1954)	Holman (1955)
Cattle used	49 mixed breeds	81 Ayrshires
R.B.C. x 10^6 (mill/ml)	5.70 ± 1.3	5.95 ± 0.765
P.C.V. (%)	37.4 ± 4.0	33.7 ± 4.14
Hb (gms %)	12.0 ± 1.5	11.3 ± 1.43
W.B.C. x 10^3 (thou/ml)	9.1 ± 1.4	7.03 ± 1.96
Lymphocytes (%)	57.0 * (36-72)	51.4 ± 11.8
Neutrophils (%)	30.0 * (12-54)	29.1 ± 9.15
Eosinophils (%)	11.0 * (2-30)	9.87 ± 11.9

* = Range of values

better agreement with the published records of Holman (1955), though again lower than many other results.

The total erythrocyte count of the Jersey animals is in much better agreement and, at 5.570 mill/ml, agrees favourably with Holman (1955) and Greatorex (1957) in England. The Friesian figure of 5.537 mlll/ml is in excellent agreement with the Jersey results of this thesis.

These differences in erythrocyte picture from published figures are almost certainly due to the different environmental conditions prevailing at the time of sampling. Not only climatic conditions, but also the effects of altitude and nutrition differences, are probably responsible. The standard deviations of the means presented here are in good agreement with all other published results, and so these means and standard errors may be considered as a good working average for haematological work on Jersey and Friesian animals in this area.

The Mean Corpuscular Volume was calculated, and the results given in Table 5. This indicates that there was little variation in cell size until October, when the size enlarged and remained so until February, when a return to the previous size was noted.

TABLE 5 Variations of the Mean Corpuscular Volume for Jersey Cows in Uganda

	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
HOME-BRED JERSEY	55.04	56.81	55.68	56.18	56.14	54.40	55.92	56.67	56.70	59.52	63.59	55.85
JERSEY ENGLAND	54.72	54.72	54.51	53.48	53.30	54.88	55.66	58.31	57.26	61.64	63.40	56.99
ALL JERSEY	54.89	55.88	54.98	54.82	54.60	54.64	55.79	57.57	57.04	60.66	63.49	56.30

(b) The leucocyte picture - The mean of the total leucocyte count of 9.720 thou/ml for all the Jersey cows is similar to Greatorex's (1957) figures from England. Holman (1955) in England gives a much lower figure, while the results from America are scattered above and below the mean given here. The Friesian result of 7.195 thou/ml agrees closely with Holman's (1955) figure, but is below the results of Greatorex (1957).

Published results normally give the percentage values for the differential leucocyte count, rather than absolute values, and for this reason the differential will be discussed with regard to the percentage count. The absolute figures are given in Tables 2 and 3. The value of the lymphocyte percentage recorded here of 66.2% seems higher than the mean of 52% found by Holman (1955) and of 57% by Greatorex (1957) in England. Thus a definite rise in lymphocyte percentage can be said to have occurred. The figure for the Friesians, though slightly lower, is of a similar order. The reverse of this picture is found when the neutrophil percentage mean of the Jersey animals is examined. The figure of 19.6 is a great deal lower than any of the published results. The Friesians show a slightly increased neutrophil percentage, but again this is well below published values.

The eosinophil percentage of the Jersey animals, 12.0, is in much better agreement with published results, Greatorex (1957) giving a mean of 11% and Holman a mean of 10%. The Friesian figure is below that of the published results in most cases. It is worth emphasising, however, that since the sampling error inherent in the differential count is so large, considerable variability must be expected from all the constituents of this count, with the larger categories being more stable than the smaller ones.

Despite all the reservations mentioned above, it does appear that a lymphocytosis and neutropaenia may have resulted from the subjection of these animals to a tropical environment.

(c) Distribution of the data

The distributions for the various blood factors of the Jersey and Friesian animals are shown in Table 6. The mean ($\bar{X}$) forms the mid-point of the table with 1, 2 and 2½ standard deviations either side. In all, 99% of all the results should be included within 2½ standard deviations either side of the mean if the distribution is normal. Examining the results for the Jersey animals it can be seen that all the distributions do approximate to normality. However, in all cases except total leucocyte count for the Jerseys, the neutrophil count of the JV animals and the total eosinophil count for all the Jerseys, slightly more than 1% of the values exceed 2½ standard deviations each side of

TABLE 6 Statistical Distribution of Blood Data

	-2½s.d.	-2s.d.	-1s.d.	$\bar{x}$	+1s.d.	+2s.d.	+2½s.d.
JERSEY							
Haemoglobin	3	4	32	84	74	39	3	1
Packed Cell Volume	0	3	35	79	86	34	0	3
Red Blood Count	2	6	29	77	90	30	5	1
White Blood Count								
ALL	0	1	33	98	72	27	7	2
JE	0	2	13	53	31	17	2	2
JV	0	0	19	44	40	12	3	2
Total Lymphocytes								
ALL	0	2	36	92	76	22	8	4
JE	0	0	13	53	40	9	2	3
JV	0	0	19	47	32	15	5	2
Total Neutrophils								
ALL	0	0	34	96	76	25	6	3
JE	0	0	14	55	33	15	0	3
JV	0	0	20	41	45	11	2	1
Total Eosinophils								
ALL	0	3	34	93	71	30	7	2
JE	0	0	17	48	36	16	1	2
JV	0	2	17	44	37	17	1	2

/Cont.

TABLE 6 (cont.)

	-2½s.d.	-2s.d.	-1s.d.	
FRIESIAN				
Haemoglobin	0	0	2	2
Packed Cell Volume	0	0	2	2
Red Blood Count	0	1	1	1
White Blood Count	0	0	1	5
Total Lymphocytes	0	0	1	5
Total Neutrophils	0	0	1	5
Total Eosinophils	0	0	1	4

$\bar{x}$	+1s.d.	+2s.d.	+2½s.d.
5	1	0	0
5	1	0	0
6	1	0	0
3	0	1	0
3	0	0	1
3	0	0	1
3	2	0	0

the mean. In all cases except for the haemoglobin distribution, the excluded values are more than 2½ standard deviations above the mean, indicating a long tail on the right of the distribution. The Packed Cell Volume distribution is the most symmetrical. These results agree with the findings of Holman (1955) except that he records a skewed distribution to the right for haemoglobin values, while these results show a skew to the left; the P.C.V. and total erythrocyte values are skewed to the right, as Holman records for his animals. All the leucocyte picture results showed a slight skew to the left, as did Holman's results. He also records that figures excluded by 2½ standard deviation appear inexplicably, though possibly by chance, as high values, as do these.

The few numbers involved in the Friesian results make deduction concerning the distribution tentative. There seems to be no reason, however, to doubt that they form part of an underlying normal distribution.

Thus, one is now able to proceed to further statistical analysis assured of the reasonable validity of one of the basic requirements underlying most analysis techniques - that of a basically normal distribution of the data.

(d) Daily Variation

The purpose of this section is to attempt to define what the expected variation from day to day of the various blood parameters might be. This variation consists of the error of the method of estimation, which is unrelated to the animal, and of individual variation and short-term environmental effects. This latter form of variability, due only to the individual animal, may be due to a readily available reservoir of cells in the spleen and reticulo-endothelial system, or to quick alterations in water balance. Holman (1955) reviews the case for both explanations, but appears to favour the former.

To estimate the amount of variation which might be expected between samples collected on succeeding days, the ten JE animals were used. Five were sampled on the first day and then re-sampled the following day. The next day the remaining five were sampled, these being re-sampled on the fourth and final day of the experiment. Blood analysis was carried out as before and the results for the means of the ten animals on the first and second day of their sampling are presented in Table 7.

From the individual daily differences the standard deviation was calculated, together with a standard error of the mean. As the number of animals used was less than thirty, the 't' value for 9 d.f. was now used to calculate 95% confidence limits of

TABLE 7 Daily Variation of

n = 10	Haemoglobin (gms %)	P.C.V. (%)
Day 1	11.07	31.10
Day 2	10.87	31.70
s.d.	0.53	2.41
s.e.	0.17	0.76
't' x s.d.	1.20	5.45
't' x s.e.	0,38	1.73

* Absolute values

some Blood Factors of the Experimental JE Cows

Blood Factor				
R.B.C. (mill/ ml)	W.B.C. (thou/ ml)	Lympho- cytes (%)	Neutro- phils (%)	Eosino- phils (%)
5.488	9.740	69.0 (6.685)*	18.1 (1.780)*	12.9 (1.274)*
5.118	9.932	68.4 (6.743)*	19.0 (1.898)*	12.6 (1.289)*
0.628	1.121	6.4 (0.732)*	7.1 (0.786)*	3.6 (0.386)*
0.199	0.354	2.0 (0.231)*	2.2 (0.249)*	1.1 (0.122)*
1.421	2.536	14.5 (1.656)*	16.1 (1.778)*	8.1 (0.873)*
0.449	0.802	4.6 (0.523)*	5.0 (0.563)*	2.6 (0.276)*

the daily variation. This was done by simply multiplying this figure (2.262) by the standard deviation and the standard error, thus giving confidence limits for both individual observations and of means of a series of observations. All these results are given in Table 7.

It is now possible to state, for example, that, if two observations on a particular cow give a Packed Cell Volume difference greater than 5.45, in nineteen cases out of twenty this effect could not be attributed to chance alone. However, since some of the error, as already stated, is not due solely to variability within the cow, but can be attributed to errors of technique, the above statement is not exactly true in the mathematical sense. The confidence limits do, however, provide a fairly accurate guide to any changes occurring, and give an indication of the magnitude of such changes.

These results are of a similar order to those recorded by Holman (1955), who calculated his figures from fifty cows of mixed breeds bled on consecutive days. He took twice the standard deviation as his 95% confidence internal; since his sample size was greater than thirty, this, statistically speaking, slightly over-estimates the 95% confidence limits. Any differences between his results and the ten used here can reasonably be attributed to the large difference in the sample

numbers. It also indicates that, although the limits given in Table 7 were calculated from Jersey animals only, they can be applied to the Friesians as well without an undue loss of accuracy.

(6) THE BLOOD PICTURE OF THE EXPERIMENTAL JERSEY CATTLE

(6) THE BLOOD PICTURE OF THE EXPERIMENTAL JERSEY CATTLE

(a) The effect of origin

The aim of this section is to try to determine if the length of time an animal remains in the tropics has any effect on its blood picture. To this end four groups of ten Jersey cows were selected, each group having a different origin. The four groups were indexed JE, JV, JG and JA. These initials were described in Chapter 4, Section (a)(i). At the end of three months the analyses of the various blood factors were examined on a group to group basis and the results are shown in Table 8. Detailed inspection of these figures indicated an age factor was having a large effect, but the various groups were not randomized for this factor, since almost all JA and JG animals were over four years old, while JE and JV animals were under this age. Since forty Friesian cattle were expected to arrive in Uganda about this time, it was felt that more profitable results could be obtained by working on the Friesian animals and measuring their adaptive changes. It was impossible to continue work on both the Jerseys and the Friesians so it was thought rational to stop further work on the JA and JG animals and concentrate on the JE and JV animals, all of which were of a similar age.

TABLE 8 Preliminary three-month analysis of the experimental Jersey animals

TEST GROUP	Hb gms.%	P.C.V. %	R.B.C. mill/ml	W.B.C. thou/ml	Lymph. thou/ml	Neutro. thou/ml	Eosino. thou/ml	Age at start
English Jersey (JE)	10.2	31.5	5.764	10.044	6.948 (69.5)*	1.709 (17.1)*	1.089 (10.9)*	mainly 2-4 years
Home-bred Jersey (JV)	9.8	30.6	5.472	9.140	6.325 (69.4)*	1.677 (18.4)*	0.857 (9.4)*	mainly 2-4 years
Kenya Jersey (JG)	9.4	29.9	4.995	7.380	4.051 (51.3)*	2.092 (26.5)*	1.500 (19.0)*	mainly over 6 years
American Jersey (JA)	9.8	30.4	5.201	9.613	5.902 (61.5)*	2.102 (21.9)*	1.315 (13.7)*	mainly 4-6 years

* Percentage values of the differential count

(i) The preliminary three-month analysis

The erythrocyte picture: The Haemoglobin, Packed Cell Volume and Erythrocyte counts could be divided into two groups, the JE and JV animals forming one group and the JA and JG the other. The younger group tended to have higher values in all three categories, but there was also an indication of a possible statistical difference between the four groups. Within these larger two groupings the JE was higher than the JV group and the JA higher than the JG group, indicating that a possible long-term effect of a tropical environment could be the lowering of the various erythrocyte counts.

The leucocyte picture: The total leucocyte and lymphocyte counts showed much the same pattern as that for the erythrocyte count. The origin effect, however, appeared much larger, since the JE and JA groups had the highest counts, followed by the JV and JG groups in that order. With the total neutrophil and total eosinophil counts the positions were reversed but, within the two larger groupings, again the JE and JA groups were similar, this time being lower than the JV and JG groups.

(ii) Twelve months analysis

On completion of twelve months sampling of the JE and JV groups, an analysis of variance procedure was used to examine

the data collected. A two-way factorial design was used, with origin and months as the two treatments. The results of this analysis are shown in Table 9.

TABLE 9 Analysis of variance results showing the effect of origin and months on the experimental Jersey animals.

Source of Variation within treatments	Hb.	P.C.V.	R.B.C.	W.B.C.	Lymph-ocytes	Neutro-phils	Eosino-phils
Origin	N.S.	N.S.	N.S.	1%	1%	1%	2½%
Months	1%	1%	N.S.	N.S.	N.S.	2½%	1%
Interaction	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

1% = Exceeds 1% significance level for 'F' test

2½% = Exceeds 2½% significance level for 'F' test

N.S. = Non Significant

There was no interaction shown between origin and months so the main effects of these two treatments can be discussed separately.

The erythrocyte picture: The erythrocyte picture did not yield any statistical difference between the JE and JV cows with regard to origin.

The leucocyte picture: The leucocyte picture, however, was shown to be considerably influenced by the origin of the cows. The total leucocyte count, together with all the various differential counts, were all affected to a considerable degree, as can be seen from Figures 4 - 7. The means and standard deviations for the various leucocytic factors of the two groups are given in Table 10.

TABLE 10 Differences in the leucocyte picture between the two groups of experimental Jersey animals.

	JERSEY ENGLAND (n = 120)	HOME-BRED JERSEY (n = 120)
Total leucocytes	10.348 ± 1.812	9.092 ± 2.064
Total lymphocytes	6.732 ± 1.294	6.113 ± 1.596
Total neutrophils	2.155 ± 0.929	1.701 ± 0.658
Total eosinophils	1.228 ± 0.580	1.077 ± 0.424

The overall increase in the leucocyte picture may indicate that the JV group had developed a better all-round resistance to infection, while the JE group was still in the process of coming to terms with its new environment.

(b) The effect of climate

Before starting the analysis of the blood results, a multiple regression analysis was carried out on the various climatic factors to see if any were related. It was already known that a regression existed between solar radiation and sun hours, and so maximum temperature, minimum temperature, rainfall, a.m. dew point and p.m. dew point were the variables selected. Each in turn was taken as the dependent variable, with the others as independent variables. From this analysis a strong correlation and regression was shown to exist in the area under study between a.m. dew point and p.m. dew point, a.m. dew point and minimum temperature and p.m. dew point and minimum temperature. Mr. D. Rijks of the Cotton Research Corporation, Namulonge, was consulted and found the results acceptable from a meteorological viewpoint. He suggested eliminating a.m. dew point, while retaining p.m. dew point and minimum temperature. The correlation between a.m. dew point and minimum temperature was $r = 0.8053$, and between p.m. dew

point and minimum temperature r = 0.8065, both with 30 degrees of freedom.

It was further decided to exclude rainfall, since the effect of this would be almost impossible to measure: in one month the rainfall could be spread evenly over each day, while in the next month all the rain could occur in two or three days, yet add up to the same amount.

Thus the final climatic parameters used were maximum and minimum temperature, p.m. dew point and sun hours.

The analysis of variance procedure used to determine the effect of origin, as has been mentioned already, was a two-way factorial arrangement. The first classification used was the JE/JV or 'origin' treatment, while the second was a monthly classification to determine if there was, indeed, any difference from month to month between the animals. The results shown in Table 9 indicate a monthly effect on haemoglobin, packed cell volume, neutrophils and eosinophils, the first two at the 1% level and the second two at the 2.5% level. These results justify a more detailed examination of the data to define these monthly effects more precisely. There was no interaction in any of the blood parameters between the effect of origin and the effect of season. The overall changes of the various blood factors from month to month are illustrated in Figures 1 - 7 and the detailed results are given in Appendices 1 and 2.

Multiple linear regression analysis was used on the blood data, taking each blood factor in turn as a dependent, and using the four climatic parameters, together with milk production, as the independent variables. The results are shown in Table 11 for those blood factors yielding significant results.

As expected, the main effects of climate and production seem to be on the erythrocyte picture, since any stress will cause the animal to make more oxygen available. Thus, with haemoglobin, a highly significant (> 1%) F-test of the regression is found. On determining 't' values to test the significance of the various partial regression coefficients, it was found that maximum and minimum temperature, sun hours and milk production were all significant at the 5% level or higher. With packed cell volume a similar highly significant regression is found, but with only maximum and minimum temperatures and milk production having a significant effect on the regression. With the total erythrocyte count, no significant regression was found, this probably being due to the greater fluctuation and variability inherent in this count.

Returning to the haemoglobin and packed cell volume results, the β-weights, or standard partial regression coefficients, were determined to find the relative importance of the various independent variables in relation to the dependent variable. From these it seemed that milk production and minimum temperature

TABLE 11 Results of multiple linear regression analysis on the erythrocyte picture of the experimental Jersey animals.

		Partial Regression Coefficient					'F' Value of Regression	D.f.	Sig. Level	'R'	Intercept	s.e. of estimate
		Max. Temp.	Min. Temp.	p.m. dew point	Sun Hours	Milk Product.						
Haemoglobin	b	0.2355	-0.5941	-0.1534	0.1048	-0.0416	19.099	5/234	1%	0.5384	16.2995	±0.8877
	s.e.	±0.0657	±0.1679	±0.1376	±0.0511	±0.0074						
	't'	3.582	-3.538	-1.115	2.051	-5.631						
	sig. level	1%	1%	N.S.	5%	1%						
	Beta Wt.	0.223	-0.310	-0.099	0.131	-0.313						
Packed Cell Volume	b	0.7594	-0.8929	0.2465	-0.1608	-01054	12.135	5/234	1%	0.4538	22.8608	±2.2144
	s.e.	±0.1640	±0.4189	±6.3433	±0.1275	±0.0184						
	't'	4.631	-2.132	0.718	-1.261	-5.722						
	sig. level	1%	5%	N.S.	N.S.	1%						
	Beta Wt.	0.305	-0.197	0.067	-0.085	-0.336						
Red Blood Count	-	-	-	-	-	-	2.435	5/234	N.S.	0.2224	-	±0.5765

were having about the same influence, followed by maximum temperature and sun hours. With packed cell volume milk production again had the greatest effect on the regression, this time followed by maximum temperature and then minimum temperature.

Since p.m. dew point - i.e. the humidity - seemed to have little effect on the regression for haemoglobin, while both this and sun hours had little influence on packed cell volume, it was decided to re-calculate the regression with these parameters left out. The main results are shown in Table 12. As can be seen, the reduction in the multiple correlation coefficient (R) is minimal and, since this is another measure of the regression, one can state that it has not been altered by the omission of these parameters.

However, with the haemoglobin regression, significance of the sun hours' parameter has now been lost - but further exclusion seems unwarranted, as it did show an effect before. The relative importance of the various parameters has also changed with re-calculation. The minimum temperature now being clearly of more importance than the milk production with maximum temperature about 40% less important than minimum temperature. The final regression equation for haemoglobin is now:

$$X = 0.2465 \text{ max. temp.} - 0.0415 \text{ milk} - 0.7382 \text{ min. temp.} + 0.0884 \text{ sun hrs.} + 15.7050$$

With the Packed Cell Volume, the 't' value of the minimum temperature partial regression coefficient is now more significant. In this case the order of importance as shown by the -weights has not altered. Thus the final regression equation is:

$$X = 0.6664 \text{ max. temp.} - 0.1075 \text{ milk} - 06704 \text{ min. temp.} + 25.2698$$

TABLE 12 Recalculation* of the multiple linear regression analysis for haemoglobin and packed cell volume levels of the experimental Jersey animals.

		Partial Regression Coefficients				'F' Value of Regression	d.f.	Sig. Level	'R'	Intercept	s.e. of estimate
		Max. Temp.	Min. Temp.	Sun Hours	Milk Production						
Haemoglobin	b	0.2465	-0.7382	0.0884	-0.0415	23.540	4/235	1%	0.5348	15.7050	±0.8882
	s.e.	±0.0650	±0.1072	±0.0490	±0.0074						
	't'	3.790	-6.888	1.805	-5.621						
	Sig. Level	1%	1%	N.S.	1%						
	Beta Wt.	0.233	-0.385	0.110	-0.312						
Packed Cell Volume	b	0.6664	-0.6704	-	-0.1075	19.672	4/235	1%	0.4473	25.2699	±2.2131
	s.e.	±0.1469	±0.2669	-	±0.0183						
	't'	4.537	-2.511	-	-5.869						
	Sig. Level	1%	2.5%	-	1%						
	Beta Wt.	0.267	-0.148	-	-0.342						

* In contrast to the results of Table 11, p.m. dew point has been excluded as a parameter in the haemoglobin calculation, while both p.m. dew point and sun hours have been excluded from the packed cell volume analysis.

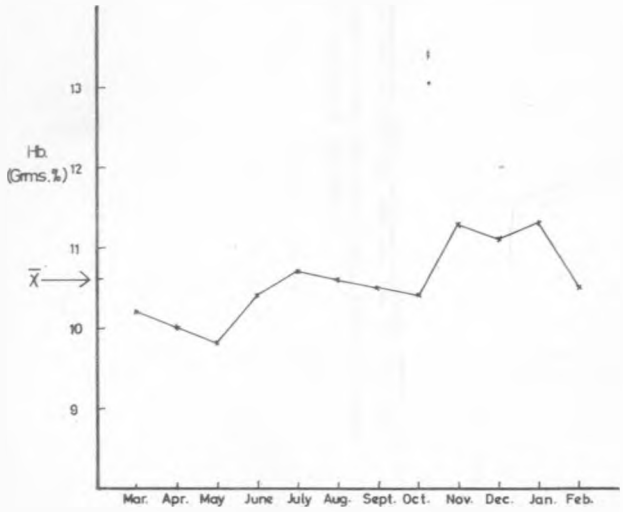

FIG.1 CHANGES IN THE HAEMOGLOBIN CONTENT OF JERSEY COWS THROUGHOUT THE YEAR

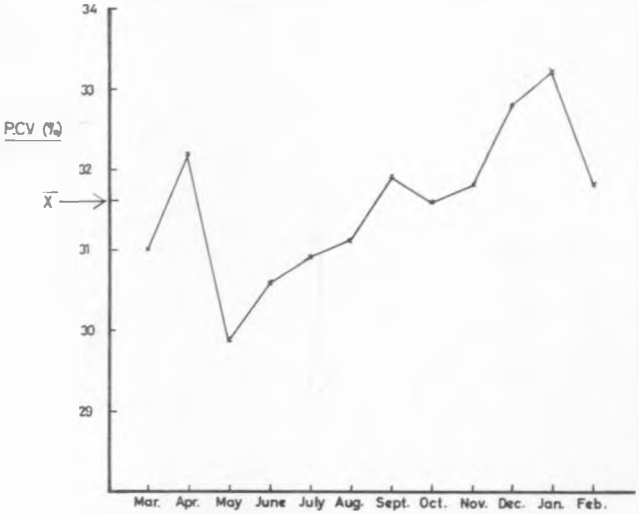

FIG. 2 CHANGES IN THE PACKED CELL VOLUME OF JERSEY COWS THROUGHOUT THE YEAR

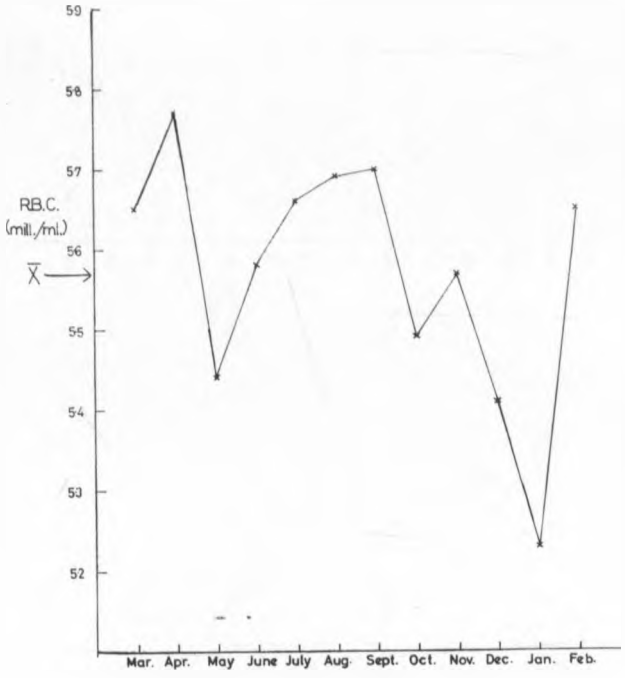

FIG.3 CHANGES IN TOTAL RED BLOOD CELL COUNT OF JERSEY COWS THROUGHOUT THE YEAR.

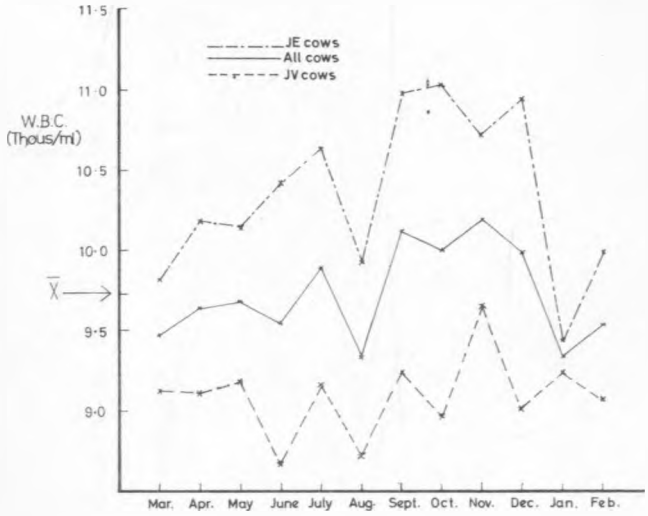

FIG. 4 CHANGES IN THE TOTAL WHITE CELL COUNT OF JERSEY COWS THROUGHOUT THE YEAR

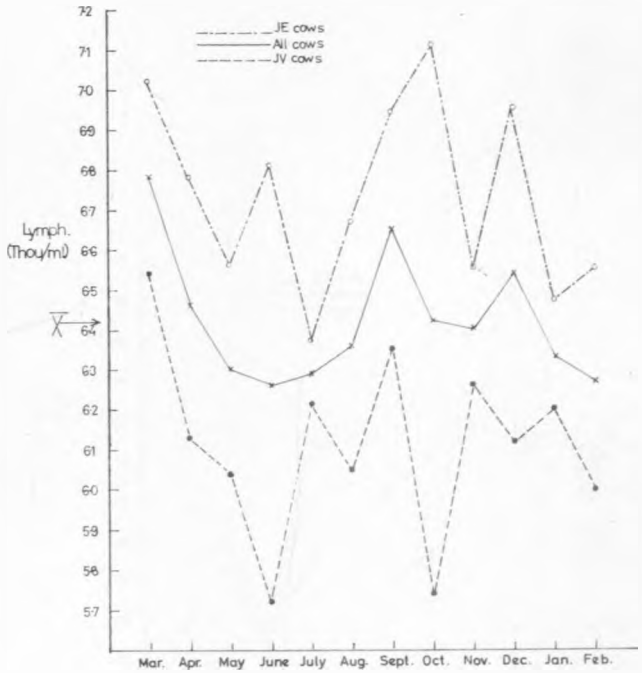

FIG.5 CHANGES IN TOTAL LYMPHOCYTE COUNT OF JERSEY COWS THROUGHOUT THE YEAR

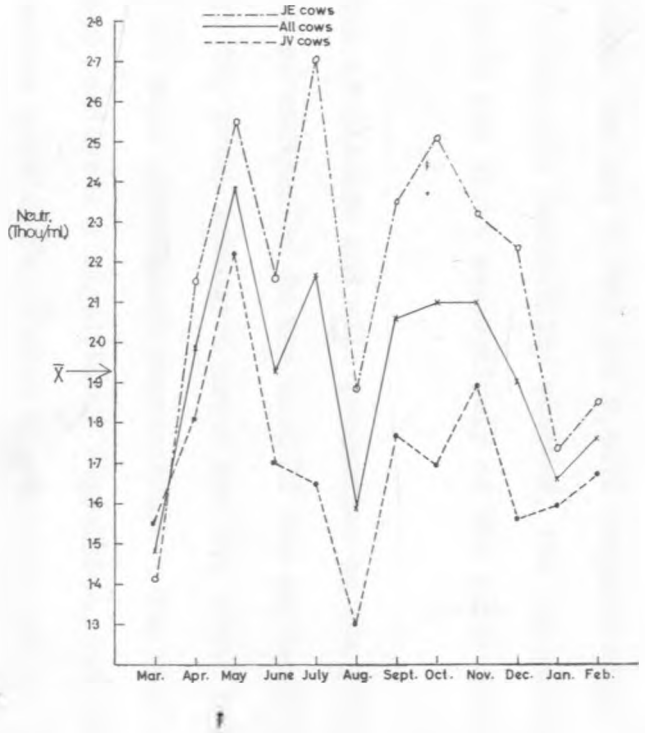

Fig.6 Changes in total neutrophil count of Jersey cows throughout the year.

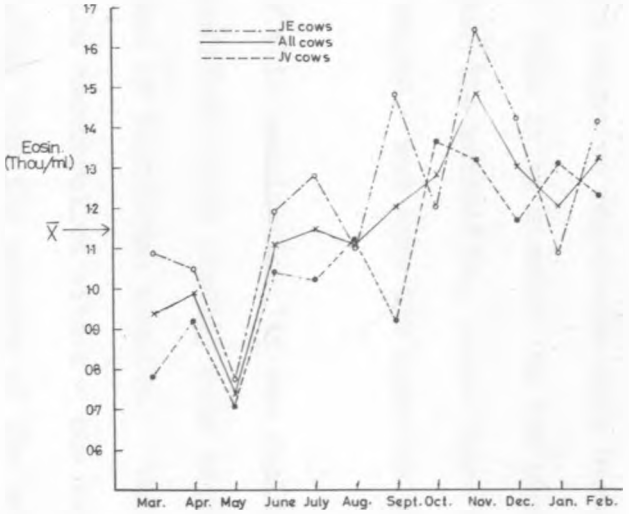

Fig.7 Changes in total eosinophil count of Jersey cows throughout the year.

An interesting point arising from these calculations is that milk production has a negative regression with haemoglobin and packed cell volume. This is an anomaly, as the greater the milk production, the higher the metabolism, hence there should be a greater demand for oxygen - but here the opposite seems to have occurred.

After the success of this examination, it was decided to re-calculate all the regressions using monthly mean values for the blood analysis, instead of individual results. This would then eliminate a lot of the uncontrolled within - cow variation. The results basically conform with the pattern of the original calculations. However, the R value for the haemoglobin and packed cell volume are now 0.9782 and 0.9076 respectively. Thus with the within-cow variability removed, the regression accounts for 95.7% and 82.4% respectively of the remaining variation.

The effects of climate and milk production on the leucocyte picture are not as obvious as in the case of the erythrocyte picture. Both the total leucocyte count and the total lymphocyte count do not show significant regressions. The total neutrophil count indicates a significant regression, but only the milk production partial regression coefficient has a significant 't' value. Again, the total eosinophil count shows a significant regression, but none of the partial regression

coefficients has a significant 't' value. On re-examining the results using monthly means instead of individual cow results for the blood analysis figures, neither of these categories of the differential showed a significant regression, and so it was considered unwise to draw any conclusions from the results.

The results are summarised in Table 13.

One secondary conclusion that may be indicated by these somewhat negative results is that there does not seem to be a seasonal variation in the rate of disease or parasitic infestation and, if this occurs at all, it is spread randomly throughout the year. The previous section on the effect of origin of the cow did indicate, however, that disease or parasitic infection may not be spread randomly between the cows, and that the JE group may be subjected to a higher infection level than the JV animals.

(c) The effect of pregnancy and lactation

To determine these effects the animals were divided into the following four groups:-

(1) Pregnant and lactating

(2) Pregnant, not lactating

(3) Not pregnant, lactating

(4) Not pregnant, not lactating

TABLE 13 Results of multiple linear regression analysis on the leucocyte picture of the experimental Jersey animals.

		Partial Regression Coefficients					'F' Value of Regression	d.f.	Sig. Level	'R'	Intercept	s.e. of estimate
		Max. Temp.	Min. Temp.	p.m. dew point	Sun Hours	Milk Product.						
W.B.C.		-	-	-	-	-	0.2736	5/234	N.S.	0.0762	-	± 2.0543
Lymphocytes		-	-	-	-	-	0.2509	5/234	N.S.	0.0730	-	± 1.4944
Neutrophils	b	-0.1228	0.1485	-0.760	0.1279	0.0160	3.1473	5/234	1%	0.2510	3.3283	± 0.8167
	s.e.	±10.1752	±0.3222	±0.3111	±0.4443	±0.0068						
	"t"	-0.7001	0.4609	-0.2444	0.2880	2.3551						
	sig. level	N.S.	N.S.	N.S.	N.S.	5%						
	Beta Wt.	-0.1451	0.0966	-0.0613	0.1997	0.1501						
Eosinophils	-	-	-	-	-	-	4.1333	5/234	1%	0.2849	-	± 0.4963

Since the work was done on a commercially-run farm, the numbers of cows falling into each group varied considerably, with very few cows in group (4). This necessitated an analysis of variance technique allowing for the unequal sub-class numbers. The method described in Steel and Torrie (1960) was used. This is basically a factorial arrangement, in which unadjusted sums of squares are calculated for the effects of lactation and pregnancy. The rest of the calculation depends on the presence or absence of interaction. The results are summarized in Table 14.

TABLE 14 Analysis of variance results showing the effects of pregnancy and lactation on the experimental Jersey animals.

Source of Variation within Treatments	Hb.	P.C.V.	R.B.C.	W.B.C.	Lympho-cytes	Neut-rophils	Eosino-phils
Lactation	1%	1%	N.S.	N.S.	N.S.	2.5%	N.S.
Pregnancy	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1%
Interaction	1%	1%	N.S.	N.S.	N.S.	5%	N.S.

No significant effect was found for the total erythrocyte count, but the other parameters of the erythrocytic picture demonstrated a significant (> 1%) interaction between lactation and pregnancy and a significant (> 1%) main effect of lactation. In the

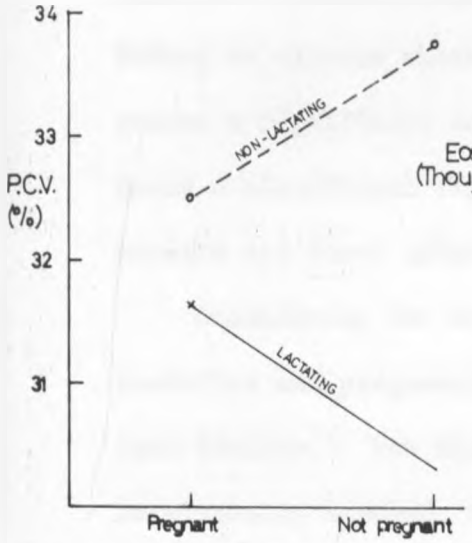

Fig.8

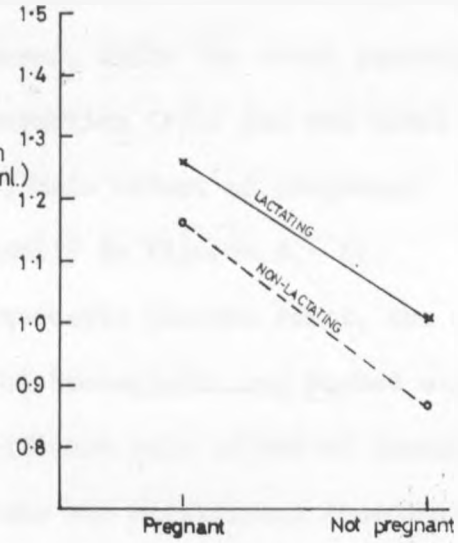

Fig.9

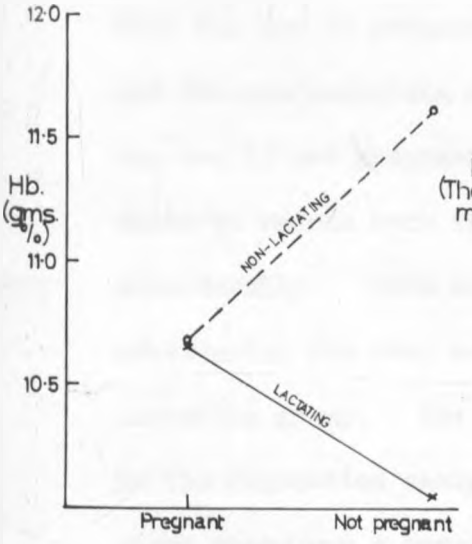

Fig.10

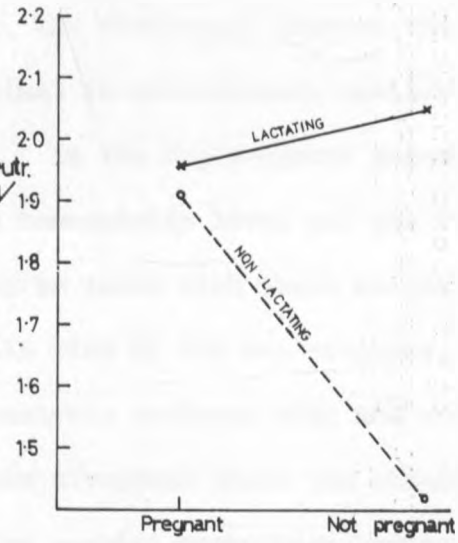

Fig.11

Fig.8 Relation of pregnancy and lactation to packed cell volume.
Fig.9 Relation of pregnancy and lactation to total eosinophil count.
Fig.10 Relation of pregnancy and lactation to haemoglobin values.
Fig.11 Relation of pregnancy and lactation to total neutrophil count.

leucocyte picture, total leucocyte and total lymphocyte counts showed no effects whatsoever, while the total neutrophil count showed a significant interaction (>5%) and the total eosinophil count a significant (>1%) main effect of pregnancy. These results are shown graphically in Figures 8 - 11.

Considering the erythrocyte picture first, the effects of lactation and pregnancy on haemoglobin and packed cell volume seem similar. The significant main effect of lactation must be virtually ignored, since the significant interaction indicates the effect depends on whether the cow is or is not pregnant. When the cow is pregnant, the difference between the lactating and the non-lactating animal is considerably smaller than when the cow is not pregnant. In the non-pregnant animal, lactation seems to reduce both the haemoglobin level and the P.C.V. level considerably. Care must be taken with these results, however, considering the very small size of the non-pregnant, non-lactating group. The analysis conforms with the results found in the regression analysis discussed under the effects of climate, where there was a negative partial regression between both haemoglobin levels and packed cell volume.

The leucocytic picture again conforms with previous findings, whereby there was a positive partial regression between milk production and neutrophil count. As with the erythrocyte picture, the difference between the lactating and non-lactating

animal in the pregnant condition is quite small, but is considerably larger in the non-pregnant animal.

The total eosinophil count is the most interesting case, since here there is no significant interaction, but a significant main effect of pregnancy, the eosinophil numbers were higher in the pregnant animal than in the non-pregnant animal. There is a small difference between the lactating and non-lactating animals, as can be seen in Figure 11, but this is almost the same in the pregnant as in the non-pregnant animal.

Because of this main effect of pregnancy, it was decided to examine the total eosinophil count further, by determining how the level changes from month to month during and immediately after pregnancy. For this purpose the results of the individual cows were classified according to the month of pregnancy of the cow at the time of sampling; the non-pregnant animals were classified into groups of one, two or three months after calving, and any remaining animals were lumped together in one group. Means were calculated for these 13 groups - 9 pregnant, 4 non-pregnant - and the results are shown graphically in Figure 12. This shows a definite rise in the count during the first two months of pregnancy, followed by a slow fall up to the fifth month. The level now falls suddenly to about the normal level for non-pregnant animals. At calving there is a further

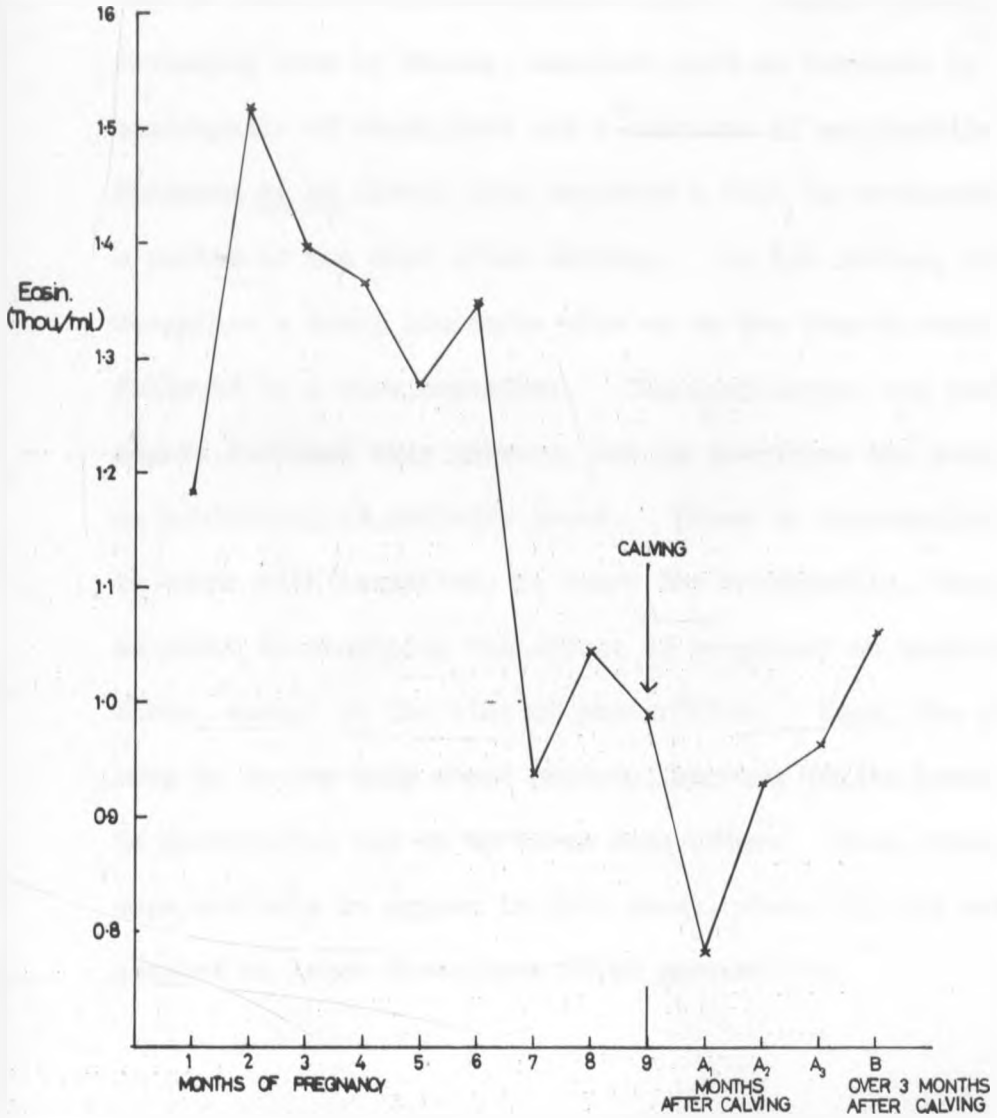

Fig.12 Changes in the total eosinophil count during and subsequent to pregnancy

decrease in numbers for the first month but, after this, the level climbs back to normal until the animal again becomes pregnant. Holman (1955) examined the effects of parturition more closely and found a neutrophilia occurred, but that there was no effect on the eosinophil count. Schalm (1965), however, reviewing work by Moberg, mentions both an increase in neutrophils of about 100% and a decrease of eosinophils of 50%. Ferguson et al (1945) also reported a fall in eosinophils over a period of ten days after calving. In his review, Schalm describes a total leucocyte rise up to the fourth month, followed by a slow recession. The lymphocytes and neutrophil counts followed this pattern, but he describes the eosinophils as exhibiting no definite trend. Since an interaction seems to occur with lactation, at least for neutrophils, there seems no point in examining the effect of pregnancy on neutrophils alone, except at the time of parturition. Here, the effects seem to be for only short periods, between twelve hours prior to parturition and up to three days after. Thus, these effects were unlikely to appear in this study, where all the cows were sampled at least three days after parturition.

(7) THE BLOOD PICTURE OF THE EXPERIMENTAL FRIESIAN CATTLE

(7) THE BLOOD PICTURE OF THE EXPERIMENTAL FRIESIAN CATTLE

Changes associated with exposure to a tropical environment

Forty Friesian animals were flown to Uganda at the beginning of August 1968 under a Danish/Uganda aid agreement programme. These animals have been described in Chapter 4, Section (a)(ii). Sampling began on these animals at the end of August 1968 and continued until February 1969. In all, the 24 animals at Kabanyolo were sampled six times, while the 16 at Entebbe were only sampled on five occasions. The results obtained for the various blood factors are shown graphically in Figures 13 - 19, and the detailed results are given in Appendices 4 and 5.

Just prior to their departure for Uganda the animals were all sampled, and blood analysis carried out, by the Statens Veterinaere Serumlaboratorium in Denmark. These results form the first point on all the graphs in Figures 13 - 19 and are labelled D. The methods of analysis used by the Danish laboratory differed from those used in this thesis in the following respects:

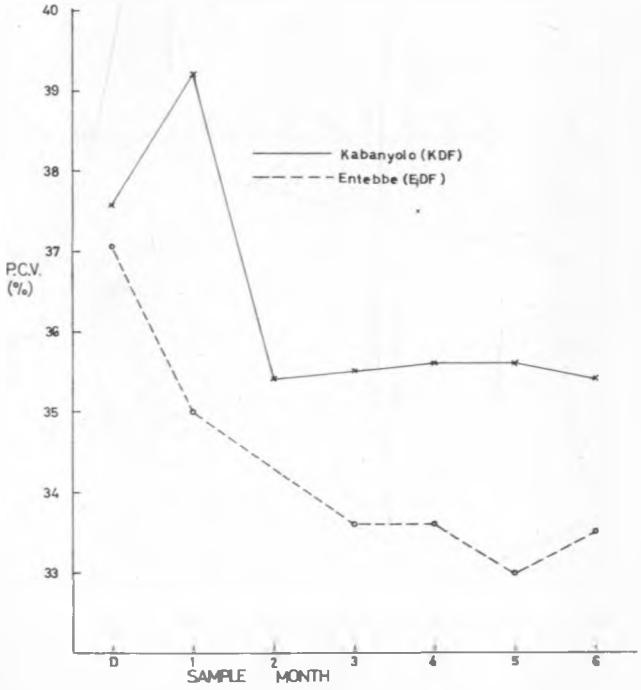

Fig.13 Changes in the packed cell volume of Friesian calves and heifers on introduction to Uganda.

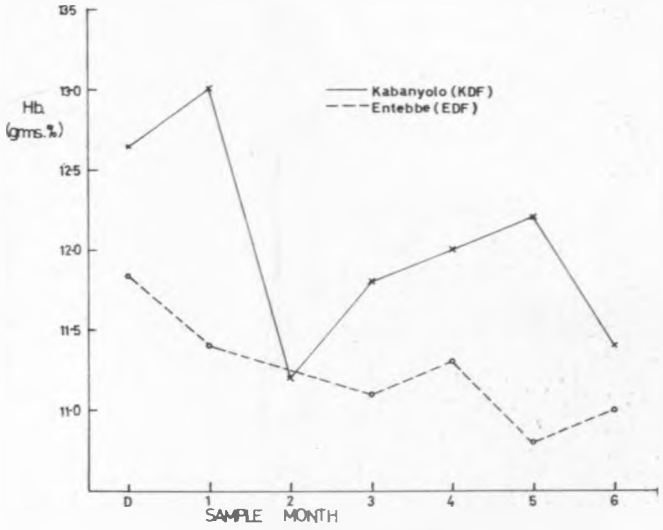

Fig.14 Changes in haemoglobin content of Friesian calves and heifers on introduction to Uganda.

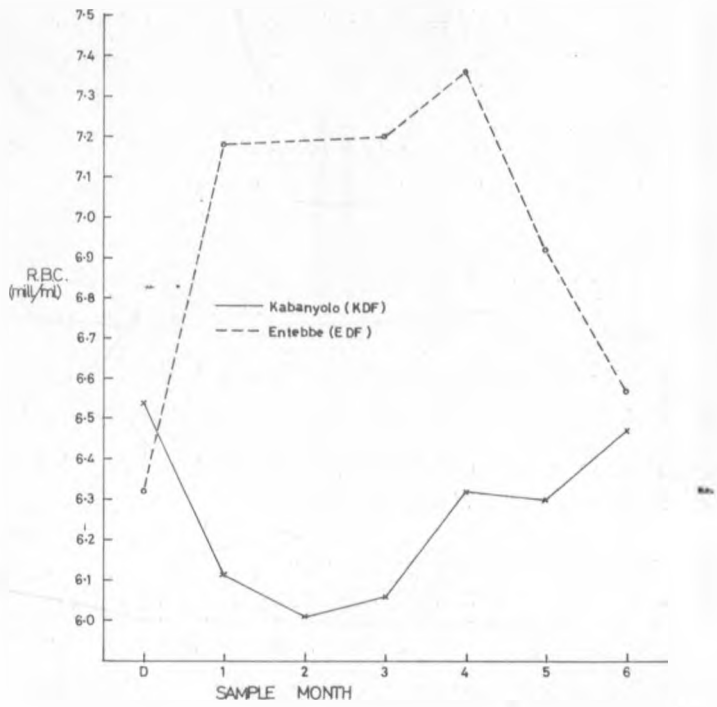

Fig.15 Changes in the red blood cell count of Friesian calves and heifers on introduction to Uganda.

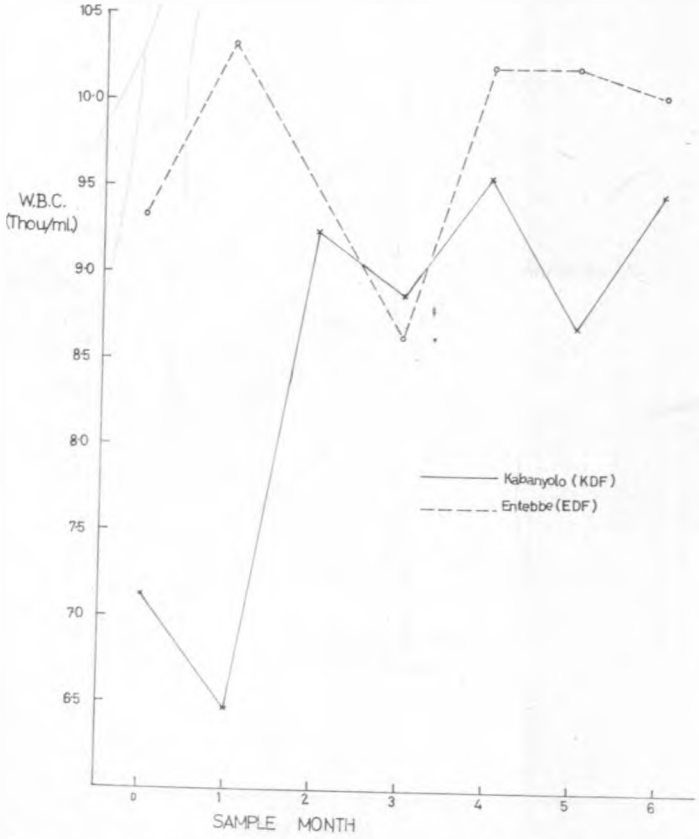

Fig.16 Changes in the white blood cell count of Friesian calves and heifers on introduction to Uganda.

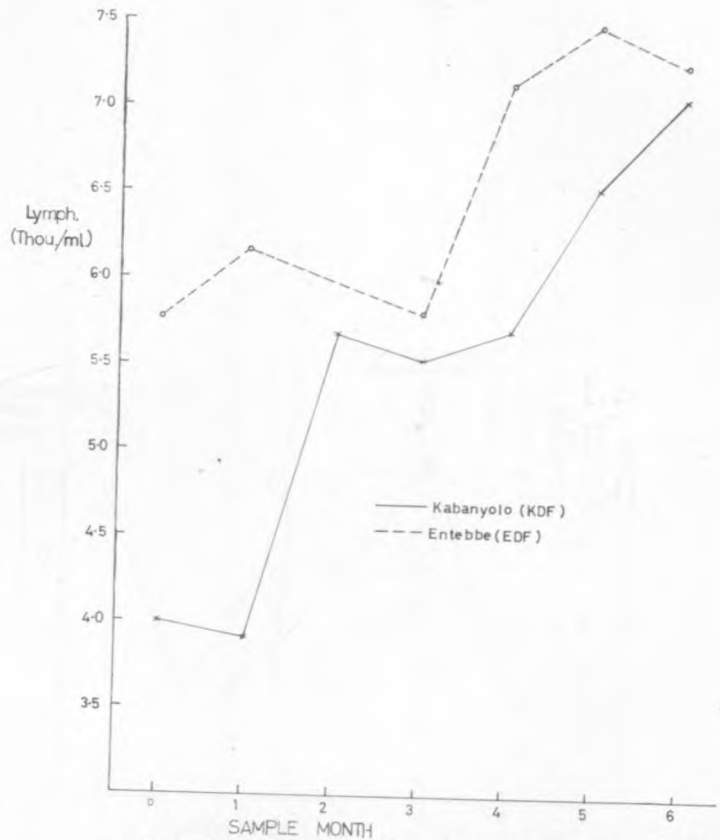

Fig.17 Changes in the total lymphocyte count of Friesian calves and heifers on introduction to Uganda.

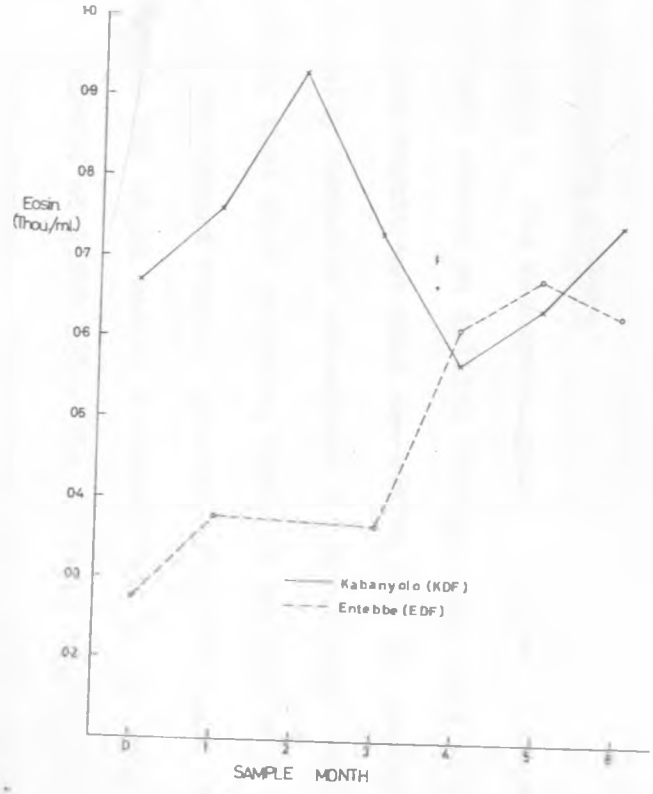

Fig.19 Changes in the total eosinophil count of Friesian calves and heifers on introduction to Uganda.

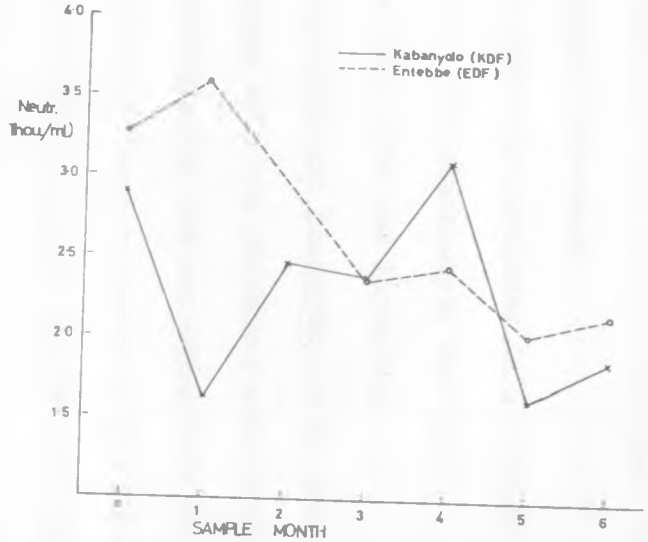

Fig.18 Changes in the total neutrophil count of Friesian calves and heifers on introduction to Uganda.

(a) Haemoglobin was determined using the oxyhaemoglobin method, the standards being checked regularly with the cyanohaemoglobin standards.

(b) Total Red Cell Count was performed in a Couther Counter model F. The electrolyte was tris-buffered saline with EDTA and formalin.

(c) Total White Cell Count was performed as in (b).

Any differences arising from the different methods used have been assumed to be minimal and did not affect the results.

Description of the changes found to occur in the blood picture during the sampling period will be described in the following two sections:

(i) The erythrocyte picture

Haemoglobin : The Kabanyolo group of Danish Friesians (designated KDF) showed an initial increase over that of their recorded Danish result but this was within the 95% confidence limits for daily variation calculated for the Jersey cows. It seems unlikely that this variation would be subject to a breed effect. On the second sample, however, after the cows had been in Uganda for eight weeks, a marked drop in the haemoglobin level was recorded of 1.84% below the previous sample, and 1.48% below the Danish reading. This was outside the 95% confidence limits of daily variation. Following this drop, there was a

steady rise up to the fifth sampling month, followed by a further drop in the final sample.

The younger animals at Entebbe (designated EDF) presented a very different picture, where a steady fall was recorded throughout most of the sampling months, except for a small upward surge after the animals had been in Uganda about fifteen weeks. The level tended to stay below that of the KDF animals, although the recorded values were about identical at one stage following the large drop in the second sample of the KDF animals.

Packed Cell Volume : The pattern here is almost identical to that of the haemoglobin values; an initial rise for the KDF animals, followed by a gradual decrease, while the EDF animals showed a fairly steady decline except for the last sampling month. In this case the decline in the KDF values never approached the results for the EDF animals, which were always lower.

Total Erythrocyte Count : A very different picture emerges here, almost a reversal of that found for the haemoglobin and packed cell volume values. The KDF animals showed an initial decrease, although this decrease did not exceed the 95% confidence levels calculated for the daily variation of the Jersey animals. This trend was reversed after about eight weeks, and was followed by a steady rise back to the level

recorded in Denmark. In the EDF animals, the opposite occurred, with an initial rise which, at its peak, exceeded the daily variation 95% confidence limits after about fifteen weeks. This was followed by a fall in recorded values but, at the end of sampling, was still higher than the equivalent Danish result.

The Mean Corpuscular Volume (M.C.V.)of the KDF animals did not show much variation during the sampling, the biggest change being 6.68 cu.μ between the Danish results and the first month of sampling. This could indicate that an initial haemoconcentration occurred, followed by a haemodilution between the first and second samples. Similar arguments applied to the EDF cows indicate the reverse, although the initial drop of nearly 10 cu.μdoes indicate a change in cell size, possibly due to altitude. The monthly means of the mean corpuscular volume, together with the result for the ten other cows of the Kabanyolo herd that were sampled are shown in Table 15.

TABLE 15 Variations of the Mean Cell Volume of the experimental Friesian animals

MEAN CELL VOLUME (cu.μ)

Sample No.	D	1	2	3	4	5	6
Kabanyolo Danish heifers	57.49	64.17	58.94	58.62	56.48	56.48	54.73
Entebbe Danish calves	58.62	48.77	-	46.68	45.63	47.67	50.95

Kabanyolo cows (KKF) = 64.49

Comparisons with Kabanyolo cows (KKF)

Comparing these results with those obtained from the ten cows sampled from the rest of the Kabanyolo herd (designated KKF), it was found that the KDF animals tended to have slightly higher haemoglobin values initially but, in the last four samples, the values were about the same. The packed cell volume was also initially higher and remained so to the end of the sampling period. The total erythrocyte count was consistently higher throughout the sampling and, at its lowest point, was still 0.469 x 10^6 mills/ml higher. The Mean Corpuscular Volume tended to be lower than the KKF result, except for the first sample, which was about the same.

The results for the EDF animals were the reverse, with consistently lower haemoglobin values and, except for the Danish figure and the first sampling figure, lower packed cell volume results. The total erythrocyte count, however, was very much larger. It must be remembered, however, that the KKF cows were sampled at about the same time as the last samples of the EDF and KKF animals and, strictly speaking therefore, comparisons should only be made between these contemporary records. The M.C.V. results for the EDF animals were consistently lower than those of the KKF animals, as would be expected in younger animals.

(ii) The leucocyte picture

Total leucocyte count : This, in the KDF animals, shows an initial small decrease when the first sample is compared to the Danish result, but is followed by a very large increase of 2.780 thou/ml. This is well outside the 95% confidence limits calculated for the Jerseys. The remaining results show a fluctuation around the 9.000 thou/ml level, with no obvious trends; the animals appear to have attained a reasonably stable state. The EDF animals recorded in Denmark show levels of about the same order that the KDF animals climb up to. However, the first sample shows an increase above this figure. This is followed by a drop below the original level and a climb back up

to this high level of about 10.000 thou/ml.

Total lymphocyte count : The KDF animals show no effect in their first results compared to their Danish figures. However, the second sample, in agreement with the total leucocyte count, shows a very large increase of 1.782 thou/ml - a difference well outside the 95% daily variation confidence limits of the Jerseys. After a very slight drop the level then continues to rise and, up to the last sample, had risen a further 1.364 thou/ml above the second sample. The EDF results remained at the same level as their Danish results - about 6.000 thou/ml - except for small fluctuations until about fifteen weeks after arrival, when a large increase was shown over the next two samples amounting to 1.680 thou/ml - a figure which again exceeds the 95% confidence limits for daily variation. The last sample showed a slight drop, to about the same level the KDF animals had climbed to. At all times the EDF animals showed larger counts than the KDF animals. It should be noted that there were no obvious reasons, such as infection or vaccination, for the change in the leucocyte picture after fifteen weeks.

Total neutrophil count : These results show a different pattern. The KDF animals exhibited an initial fall below the Danish level, though this did not exceed the 95% confidence

limits of daily variation. An increase in numbers now followed, back to the Danish level at the fourth sampling. A further decrease, of the same order as the first drop, was now recorded; at the last sampling the level had risen again, but only to a small degree. The EDF animals showed an initial small rise above the Danish level, followed by a fairly consistent drop which only levelled out at the last two samplings. The total recorded fall was just inside the 95% confidence limits of daily variation. Apart from the first sample taken from the two groups, the neutrophil levels of the KDF and EDF animals was of much the same order.

Total eosinophil count : This did not show as much variation in the KDF animals as was exhibited by the other differential leucocyte counts. The first two samples showed an increase over the Danish figure, but this was well inside the 95% confidence limits of daily variation. A drop now occurred over the next two samples to below the Danish level, but again this drop was within the 95% confidence limits. The last two samples showed a slight increase, which ended at just above the Danish level. The EDF animals demonstrated a gradual rise above the Danish figure, but again the total rise was within the confidence intervals. The last three samples were of about the same order and were at almost the

same levels as the last three KDF results.

Comparisons with Kabanyolo cows (KKF)

On comparing the results of the leucocyte picture with the KKF animals (see Table 3), it is found that the original Danish results of the KDF animals were about the same for total leucocytes, total lymphocytes and total eosinophils, but higher for total neutrophils. After the first sampling, however, the remaining KDF results and all of the EDF results - including the Danish figure - were considerably higher than the KKF count, and to a degree that exceeded the 95% confidence levels of daily variation. The same results were found when examining the lymphocyte counts of the three groups - the EDF animals were always in excess of the KKF group, while the KDF animals were in excess after the first sample.

Although the Danish result for the neutrophil count was higher than the KKF result, the level dropped at the first sampling to a comparable level. The following rise took the level above the KKF results again, but the last samples were almost identical to the KKF figures. The EDF animals had continual higher readings for neutrophil counts, but the steady fall of most of the samples brought the last two readings to a level only slightly higher than the KKF results.

The eosinophil counts showed the KDF animals as having

continual higher levels than the KKF animals, though the largest difference was not outside the 95% confidence intervals of daily variation. The initial Danish result and the first two sample results of the EDF animals were comparable to the KKF animals, and it was not until the third and subsequent samples that any sizable differences appear, though even these were within the 95% confidence limits of daily variation.

As was mentioned earlier, the KKF animals can only, strictly speaking, be compared with the last samples of the KDF and EDF animals. When this is done, it becomes clear that there is a large difference between the total leucocyte count and the total lymphocyte counts of both the KDF and EDF animals as compared with the KKF figures. The total neutrophil counts of the KDF and EDF groups are slightly higher than the KKF group, while the eosinophil counts of the KDF and EDF groups are considerably higher than those of the KKF group. However, these differences were not of the same degree found with the total leucocyte and total lymphocyte counts.

These results of the leucocyte picture agree with those of the Jersey cows. The newly arrived animals showed increased counts in the various parameters making up the leucocyte picture, as compared with the results found for a group of reasonably similar animals that had been bred under the prevailing, or very

similar, conditions. Again this indicates a stress response, the animal preparing to, or in some cases really withstanding, challenges of a type and possibly on a scale not encountered in its previous environment.

(8) DISCUSSION

(8) DISCUSSION

(a) Measurements of stress via the blood picture

Under conditions of stress, Schalm (1965) states that the adrenal cortical secretion depresses the number of circulating eosinophils and lymphocytes and leads to an elevation in number of circulating neutrophils. A haemoconcentration may also occur. The triad of neutrophilia, eosinopenia and lymphopenia following stressful stimuli is commonly seen in both the stress of disease, and of parturition. With regard to the total leucocyte count, the cow is less responsive to stress than many other animals. The reason for this is found by examining the ratio of total neutrophils to total lymphocytes. In the cow this is quoted as being in the region of one to two (Schalm, 1965). With several other animals such as the dog, or man, this ratio is reversed, there being larger numbers of neutrophils than lymphocytes. Under stress conditions, the cow will respond in a similar manner to the dog, man or other animals, but the initial fall in number of circulating eosinophils and lymphocytes may exceed the increase in number of neutrophils, with the effect of an actual reduction in total leucocyte count. In the dog and man, a similar response to stress would result in a large increase in number of circulating leucocytes, due to an initially higher

proportion of neutrophils.

A further response to stress that may be observed in the blood of the cow is known as a shift to the left. This is characterised by a neutrophilia and by the appearance of immature neutrophilic granulocytes in peripheral blood in excess of that normally encountered. Generally more than two per cent band cells or the occurrence of younger forms is interpreted as a shift to the left (Schalm, 1965). No investigation of these immature neutrophilic granulocytes was undertaken in this study due to the volume of work this would have involved. Most investigations of this type are carried out on only a few animals. No indication was therefore obtained as to whether or not this shift to the left occurred at any time during the experiment.

The results for the Jersey animals did not demonstrate the classical picture of a stress response. The comparison between the home-bred (JV) and English (JE) animals indicates an increased total leucocyte count of a size that could indicate a stress response. However, all the main components of the differential leucocyte count were also elevated. This does not mean, however, that no stress response is present. It could indicate that the initial stage of the general adaptation syndrome, the alarm-reaction, had passed, and that this picture represents the stage of resistance. Also, the animals may have responded to an

invasion of disease organisms not previously encountered, and this may also have confounded the observed picture. No evidence for haemoconcentration was observed, which would tend to indicate that if a stress reaction was present, it was not severe.

The Friesian animals from Denmark (KDF and EDF) also showed initial increases in leucocyte counts, as compared with their Danish values. However, the triad of a classical stress reaction - neutrophilia, lymphopenia and eosinopenia - was again absent. This may have been due to their being exposed to infection by organisms not previously encountered, or there may have been no stress reaction. The overall leucocyte picture, however, was one of change, and this does suggest that a modified stress reaction was occurring.

Haemoglobin values have been suggested as a possible index of heat tolerance by Findlay (1950). This view received support from Rusoff et al (1951), working at Louisiana, who found that Red Sindhi-Jersey cows had higher haemoglobin and packed cell volume than their dams. Walker (1958), working in Northern Rhodesia, investigated the relationship between changes in the haemoglobin index with age and the development of the heat tolerance coefficient as measured by the Iberia heat test (Rhoad, 1944). He worked with three indigenous breeds of cattle and the Friesian and Jersey. He calculated the correlation between the heat tolerance coefficient and the haemoglobin index as $r = + 0.2561$, which was

significant at better than the 1% level. This work agreed with the findings of Manresa, Gomez and Santos (1939). It should be pointed out, however, that this r value only accounts for 6.8% of the variation of the correlation. Walker goes on to state that the association between the heat tolerance coefficient and the haemoglobin index was not a direct linear relationship, but one of degree of change. The more rapidly the haemoglobin index changed from his highly variable juvenile figure to the relatively stable mature figure the more rapid was the development of heat tolerance, which however continued to be closely correlated with a high haemoglobin index ($r = + 0.3004$, significance 0.1%). The present findings do not agree with the argument that haemoglobin is an index of heat tolerance, but do not clarify the issue.

Since milk production is one of the chief aims of keeping cattle, high production can well be taken as an indication of good heat tolerance. It will be noted from the multiple regression equation in Chapter 6, Section (b), that the partial regression coefficient for milk production is negative in both the equations for haemoglobin and packed cell volume. This situation will be discussed more fully in Section (b) of this discussion.

Also, at the hottest times of the year the haemoglobin values are highest. At these times of high temperatures, the maximum values are recorded during the day, while the minimum

values are recorded at night. This is due to a cloudless sky permitting the sun to warm the land during the day. At night, however, radiation into space is considerable due to the absence of insulating cloud cover. Thus, it could be that it is not how high the temperature goes during the day that is important, but how low it goes. Since the mean annual temperature is about 71.5°F (22°C), the temperature for most of the day will be outside the comfort zone suggested by Brody (1956). Thus the cow is probably subjected to heat stress during the day, but if this heat can be 'stored' by a rise in body temperature, and then dissipated during the relative cool of the night, minimum temperature would be an important governor of heat stress. The lower the temperature the more easily this stored heat could be dissipated. This hypothesis also leads on to the accepted view that the most heat-tolerant animal is the one that can withstand a rise above normal body temperature without undue harm resulting.

Thus, although the heat stress during the day may be high, low minimum temperatures may be controlling the situation, and the high haemoglobin index may indeed be indicating a better adaptation at these times.

Heat stress and milk production both appear to cause similar responses in the blood picture. Both would cause an increase in the haemoglobin values and packed cell volume percentage, to ensure

that adequate supplies of oxygen are available; in the first case to meet any emergencies that might result from the stress, and in the second to meet the demands of the metabolic processes of milk production. However, since the heat stress is probably of a chronic rather than acute nature, its requirements should be fairly stable. Thus, if this were the case, any changes in demand for oxygen, as reflected by the values of haemoglobin and packed cell volume, would be due solely to milk production requirements.

It would appear from the data presented, that apart from the haemoglobin values and packed cell volume records already discussed, total eosinophil and neutrophil counts are the only remaining blood factors that might indicate heat-tolerance or adaptation to heat stress. These were the only other factors that showed a significant seasonal effect. As already noted, these also showed significant multiple regressions with climate and production. Unlike the haemoglobin and packed cell volume regressions, which accounted for 28.6% and 20.0% of the variability using individual results, the total eosinophil and neutrophil values only accounted for 8.1% and 6.3% of the variability. Further, the regressions using the mean results were non-significant, while the similar regressions for haemoglobin and packed cell volume accounted for 95.7% and 82.4% of the total variation. Little information therefore appears to be available, in this respect, from these

results.

A final point of interest arising out of the Friesian data is the large difference between the changes in the blood picture of the calves as compared with the heifers. Both the haemoglobin and packed cell volume levels of the calves were subject to less change than the corresponding values for the heifers. This may indicate that calves are more adaptable than older animals. Alternatively, it may indicate that the calves were unable to respond to the imposed heat stress, while the heifers were able to respond. This point would be clarified by future investigations into the comparative production records of the calves and heifers.

(b) Milk production in the light of the blood analysis data

It has been noted (Redfern, 1968b) that clinical signs of heat stress such as panting, excessive salivation, increased heat rate and raised rectal temperatures may not be as significant an indication of heat stress, as productive traits. Lowered productivity in terms of growth, reproductive ability and milk yield may be more significant indications of the adverse effects of a hot environment, in the absence of disease and inadequate management and nutrition. These functions are, to a large degree, controlled by endochrine organs. The little experimental data published on this subject has been reviewed by Redfern (1968b),

who noted that it indicates a stress-induced 'shift' in endocrine function of Bos taurus dairy breeds in hot environments. He points out that the triad of neutrophilia, lymphopenia and eosinopenia indicates an increased adrenocortical function. Thyroid activity appears reduced, and the low breeding efficiency in Bos taurus animals in hot climates suggests a decline in ovarian function. This shift of emphasis in endocrine function may account for the low milk production records of Bos taurus dairy breeds already noted.

As previously mentioned, the classical triad of the general adaptation syndrone (Selye, 1950) was not observed in the results of this experiment; also there was no haemoconcentration of the blood, another index of the general adaptation syndrone. However, it was shown from the regression equations of haemoglobin and packed cell volumes with climate and production, that milk production tended to be low at the hottest times of the year. The figures used for milk production in these regression equations were the average daily production, in pounds, for the week during which the blood sample was taken. If a cow was dry at the time, its production was given as zero. This fact may have biased the results. If not, this would indicate that high temperatures were causing a decrease in milk production, either through a shift in endocrine function or indirectly via the forage.

The calculated regression equations allow expected haemoglobin and packed cell volume values to be calculated for the conditions of climate and production recorded. By examining the deviations of these estimated haemoglobin and packed cell volume results from their actual values, it was possible to pick out the cows that were either well above or well below the estimate. One standard error of the estimated regression was chosen as the limit either side of the true estimate. By using these results from both the haemoglobin and the packed cell volume figures, the animals listed in Table 16 appeared the most 'Abnormal'.

TABLE 16 Jersey cows whose blood values differed by more than 1 s.e. above or below the mean from their expected values of haemoglobin and packed cell volume, together with their mean milk production figures.

Breed	More than 1 s.e. above the estimate		More than 1 s.e. below the estimate	
	Cow No.	Mean Production	Cow No.	Mean Production
Jersey England (JE)	154; 156; 188	14.5 lb/day/cow	80; 95; 122	14.1lb/day/cow
Home-bred Jersey (JV)	745; 746; 737	13.6 lb/day/cow	736; 741; 744; 753	12.7lb/day/cow

It should be pointed out that these cows were not abnormal every month, but on more than seemed due to chance alone. By taking their daily production figures, and calculating a mean daily production figure for those above and those below the mean, ignoring any results where an animal was dry, the production figures shown in Table 16 were obtained. The mean for all cows above the estimate was 14.0 lb/day/cow, while for those below the estimate it was 13.4 lb/day/cow. The mean daily production figures for all the cows, when in milk, are shown in Table 17.

TABLE 17 Mean daily milk production record for JE and JV cows in milk during the experiment.

Jersey England	:	14.7 lbs/day/cow
Home-bred Jersey	:	12.7 lbs/day/cow
All Cows	:	13.8 lbs/day/cow

From these results, the cows listed did not appear to have increased or decreased milk production results. It is interesting to note the difference in production levels of the JE and JV animals, which may show that the length of time these animals have spent in the tropics has affected their production. The results could be caused by several factors, however - most notably, their breeding and genetic potential. Their dams were Kenyan Jerseys

(JG) in some cases and American Jerseys (JA) in others. The JG animals could well be inferior breeding animals when compared with the dams of the JE animals, which were specially selected.

Due to the lack of definite results in these techniques of analysis, simple regressions were calculated between the monthly mean milk production figures of those animals in milk, and mean monthly maximum, and then minimum, temperatures. However, the regressions were non-significant.

Finally, it was decided to investigate the persistency records of the cows' lactation, to determine if this was influenced by season and, if so, whether this was reflected in the blood picture. By the end of the experiment, records were available for the first lactations of all twenty cows of the Jersey group, and wholly or partly for the second lactation of eight of the animals. Ignoring the calendar month in which the animal calved down, the results of Tables 18 and 19 are obtained.

TABLE 18 Persistency records for Jersey cows, taking the previous lactation month as 100%

Month of Lactation	Mean daily milk production (lbs)		% Persistency from previous month	
	1st Lactation	2nd Lactation	1st Lactation	2nd Lactation
1	18.5	21.7	-	-
2	16.6	20.1	89.7	92.6
3	13.7	17.6	82.8	87.6
4	12.1	17.1	88.0	97.2
5	11.7	15.9	97.1	92.6
6	10.9	14.7	93.2	92.7
7	10.8	14.1	98.6	96.1
8	10.4	12.4	96.3	87.9
9	10.2	11.3	97.7	91.9
10	8.9	10.7	87.6	94.9

Average persistency = 92.3%

TABLE 19 Persistency records for Jersey cows, taking the first month of lactation as 100%.

Month of Lactation	1st Lactation	2nd Lactation
1	100.0	100.0
2	89.7	92.6
3	74.1	81.1
4	65.4	78.8
5	63.2	73.3
6	58.9	67.7
7	58.4	65.0
8	56.2	57.1
9	55.1	52.1
10	48.1	41.3

Thus, in the first lactation at least, the biggest decreases in production occurs soon after the peak, and this is followed by a levelling out of the lactation curve. The average persistency of 92.3% compares well with Kartha (1934) who gives a figure of 91.2% for crossbred cows in the tropics, and 92.8% for Pedigree sahiwal cows.

When these figures are re-calculated on the basis of calendar months instead of lactation months, the results of Table 20 are obtained.

TABLE 20 Mean Persistency Levels of Jersey Cows throughout the year.

Calendar Month	Mean % Persistency
January	91.2
February	83.8
March	111.6
April	94.7
May	94.4
June	89.7
July	86.8
August	88.3
September	106.9
October	96.1
November	94.9
December	92.8

These results clearly show a seasonal trend in milk production. March and September both show increases in persistency instead of the expected decrease while falls in persistency occur in February and July. Reference to Figures 1-7, however, will show that there was no correlation between changes in this persistency and the variations observed in the blood picture. What appears to be happening is that milk production is stimulated indirectly by increased rainfall promoting superior forage growth. This

stimulus to milk production is not, as might be expected, reflected in the blood picture.

It is interesting to speculate as to what effect the low level of productivity of the Jersey animals had on the findings of this experiment. By comparing the results of Table 1 with those presented by Kiwuwa (1968) from Kenya, it may be seen that the production records of the experimental Jersey animals are much lower. The experimental Jersey animals were mainly first calvers, and so this might be expected. However, at this level of production, the direct effect of the environment may be masked by the greater indirect effect of forage quality, which of course is also controlled by the climate.

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(10) APPENDICES

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APPENDIX 1 Monthly means of the erythrocyte picture of the experimental Jersey cows.

Month	Haemoglobin (gms %)			Packed Cell Volume (%)			Red Cell Count (mill/ml)		
	JE	JV	ALL	JE	JV	ALL	JE	JV	ALL
March	10.5	9.8	10.2	32.2	29.8	31.0	5.885	5.414	5.649
April	10.1	9.9	10.0	32.0	32.3	32.2	5.848	5.686	5.767
May	9.9	9.7	9.8	30.3	29.6	29.9	5.559	5.316	5.438
June	10.3	10.5	10.4	30.1	31.1	30.6	5.628	5.536	5.582
July	10.8	10.6	10.7	30.7	31.2	30.9	5.760	5.558	5.659
August	10.4	10.8	10.6	30.9	31.3	31.1	5.630	5.754	5.692
September	10.6	10.4	10.5	31.8	31.8	31.8	5.713	5.687	5.700
October	10.5	10.2	10.4	31.5	31.6	31.6	5.402	5.576	5.489
November	11.5	11.1	11.3	31.7	32.0	31.8	5.536	5.614	5.575
December	11.2	11.1	11.1	33.2	32.3	32.8	5.386	5.427	5.407
January	11.2	11.5	11.3	33.1	33.3	33.2	5.221	5.237	5.229
February	10.4	10.6	10.5	31.3	32.3	31.8	5.492	5.804	5.648

APPENDIX 2

MONTH	White Cell Count (thou/ml)			Lymphocyte Count (thou/ml)			Neutrophil Count (thou/ml)			Eosinophil Count (thou/ml)		
	JE	JV	ALL	JE	JV	ALL	JE	JV	ALL	JE	JV	ALL
March	9.809	9.123	9.466	7.016	6.544	6.779	1.412	1.555	1.483	1.094	0.785	0.939
April	10.180	9.107	9.643	6.785	6.127	6.456	2.154	1.808	1.981	1.048	0.934	0.991
May	10.145	9.188	9.667	6.561	6.039	6.300	2.551	2.218	2.384	0.769	0.709	0.739
June	10.410	8.675	9.542	6.807	5.719	6.263	2.163	1.700	1.932	1.193	1.036	1.115
July	10.622	9.152	9.887	6.375	6.208	6.291	2.697	1.652	2.174	1.285	1.019	1.152
August	9.937	8.720	9.329	6.674	6.049	6.361	1.879	1.305	1.592	1.103	1.121	1.112
September	10.972	9.240	10.106	6.939	6.354	6.647	2.353	1.771	2.062	1.478	0.924	1.201
October	11.025	8.962	9.994	7.111	5.738	6.425	2.514	1.693	2.103	1.198	1.372	1.285
November	10.722	9.639	10.181	6.554	6.256	6.405	2.318	1.892	2.105	1.643	1.325	1.484
December	10.937	9.015	9.976	6.949	6.125	6.537	2.232	1.560	1.896	1.425	1.168	1.296
January	9.442	9.231	9.331	6.466	6.200	6.333	1.730	1.587	1.658	1.088	1.306	1.197
February	9.978	9.062	9.520	6.552	5.996	6.274	1.852	1.672	1.762	1.413	1.233	1.323

APPENDIX 3 Climatic data for Namulonge Station:* Means for ten days prior to middle of sampling period.

MONTH	Maximum Temperature (°C)	Minimum Temperature (°C)	p.m. Dew Point (°C)	Sun Hours (hrs.)	Rainfall
March	26.97	16.88	18.16	4.78	
April	27.31	16.99	18.48	4.44	
May	26.45	16.81	18.68	7.33	
June	26.84	16.05	18.26	5.97	
July	25.49	15.38	16.37	4.79	
August	26.63	15.78	17.13	4.52	
September	27.79	16.10	17.49	4.79	
October	28.46	17.07	18.37	7.24	
November	28.53	16.09	17.27	8.24	
December	27.64	15.67	18.23	7.06	
January	29.21	15.81	17.14	6.24	
February	27.70	16.71	17.91	4.55	

* Namulonge Station adjacent to Nakyesasa and Kabanyolo farms

APPENDIX 4

SAMPLE NO.	Haemoglobin (gms %)		Packed Cell Volume (%)		Red Cell Count (mill/ml)	
	KDF	EDF	KDF	EDF	KDF	EDF
Denmark	12.64	11.84	37.58	37.06	6.537	6.322
1	13.0	11.4	39.2	35.0	6.109	7.177
2	11.2	-	35.4	-	6.006	-
3	11.8	11.1	35.5	33.6	6.056	7.198
4	12.0	11.3	35.6	33.6	6.322	7.363
5	12.2	10.8	35.6	33.0	6.303	6.923
6	11.4	11.0	35.4	33.5	6.468	6.575

APPENDIX 5

SAMPLE No.	White Cell Count (thou/ml)		Lymphocyte Count (thou/ml)		Neutrophil Count (thou/ml)		Eosinophil Count (thou/ml)	
Denmark	7.254	9.325	3.996	5.771	2.587	3.278	0.670	0.275
1	6.457	10.323	3.909	6.164	1.634	3.594	0.756	0.378
2	9.237	-	5.691	-	2.457	-	0.934	-
3	8.868	8.644	5.533	5.802	2.390	2.364	0.731	0.369
4	9.562	10.198	5.701	7.129	3.104	2.455	0.568	0.615
5	8.698	10.206	6.533	7.483	1.634	2.045	0.644	0.679
6	9.480	10.046	7.054	7.246	1.890	2.163	0.747	0.634

APPENDIX 6 **Individual results for the haemoglobin values** of the experimental Jersey animals

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	9.2	9.1	10.2	10.2	10.2	10.6
JV 738	10.1	10.0	10.0	11.3	10.4	11.5
JE 154	12.4	10.5	11.1	11.0	12.2	11.2
JV 741	9.5	9.3	9.0	10.2	10.2	9.8
JE 156	11.4	10.4	9.7	10.5	10.6	10.6
JV 732	10.1	9.3	10.0	10.7	10.6	10.7
JE 188	10.6	11.7	9.8	11.0	10.6	10.8
JV 744	8.3	8.7	7.6	7.6	7.9	8.4
JE 56	10.5	9.9	9.5	10.1	9.9	9.2
JV 753	9.4	9.3	9.2	9.9	9.6	9.0
JE 165	10.7	9.9	10.8	10.3	10.5	9.9
JV 736	9.6	10.2	9.7	10.2	10.3	10.4
JE 180	9.7	9.9	9.2	10.1	11.8	10.7
JV 746	10.2	10.8	10.4	10.1	12.6	11.0
JE 161	10.9	8.9	9.3			
JE 121				9.4	10.7	9.9
JV 737	10.4	11.7	10.7	11.9	11.0	12.5
JE 133	10.4	11.1	10.1			
JE 85				10.6	11.3	11.0
JV 747	9.6	10.2	10.1	12.1	11.3	13.0
JE 78	9.7	9.2	8.9			
JE 95				9.6	10.6	10.2
JV 751	11.2	9.3	10.1			
JV 745				11.5	11.7	11.9

APPENDIX 6 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	10.2	10.2	11.1	11.1	11.0	10.5
JV 738	12.3	11.0	11.7	12.4	(12.2)	(11.2)
JE 154	10.8	10.7	12.7	12.5	12.0	11.2
JV 741	10.4	10.3	(10.7)	(10.7)	(11.1)	(10.2)
JE 156	10.8	10.8	12.7	12.0	12.0	10.9
JV 732	10.2	10.8	11.7	10.8	12.2	10.9
JE 188	11.3	12.5	12.2	12.5	12.2	11.5
JV 744	8.4	9.1	9.4	10.1	10.1	8.8
JE 56	9.5	9.9	11.2	10.6	10.8	9.5
JV 753	10.8	10.4	11.5	(10.7)	11.0	10.3
JE 165	9.8	9.7	11.9	10.1	11.4	10.4
JV 736	9.3	9.5	10.4	10.9	10.1	9.2
JE 180	9.6	9.7	10.1	10.2	10.6	10.4
JV 746	9.3	9.7	10.4	10.4	10.7	9.8
JE 121	11.9	10.4	11.9	11.2	11.1	10.6
JV 737	12.4	10.3	11.7	11.5	13.7	11.5
JE 85	11.8	11.6	12.0	12.0	11.2	10.3
JV 747	9.8	10.8	(11.7)	(11.7)	(12.1)	(11.2)
JE 95	10.4	9.9	9.3	9.5	9.3	8.9
JV 745	11.4	10.2	12.0	12.1	11.9	12.6

( ) indicates missing plot estimate.

APPENDIX 7 Individual results for the packed cell volume values of the experimental Jersey animals.

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	28.5	30.5	30.5	28.5	29.5	31.5
JV 738	29.5	32.7	32.0	31.0	31.5	33.5
JE 154	33.5	34.5	33.0	32.0	34.5	33.0
JV 741	29.0	32.0	26.5	28.0	30.5	29.0
JE 156	34.2	33.0	29.5	30.5	30.5	31.5
JV 732	31.7	33.0	31.5	32.5	31.5	32.5
JE 188	34.0	33.0	29.5	30.5	30.5	32.0
JV 744	27.0	27.0	30.0	26.0	25.5	27.0
JE 56	32.2	29.7	29.5	31.5	29.5	27.5
JV 753	29.5	32.7	27.5	30.0	28.0	28.0
JE 165	35.2	34.7	33.0	31.5	30.5	28.5
JV 736	29.5	33.2	30.0	30.5	30.5	30.5
JE 180	30.7	31.2	29.5	30.0	32.0	33.0
JV 746	30.5	33.7	29.5	30.5	33.5	30.0
JE 161	34.0	28.5	27.0			
JE 121				27.0	30.5	28.5
JV 737	33.0	34.7	27.0	33.5	35.0	35.0
JE 133	31.5	34.7	31.0			
JE 85				31.0	30.5	32.0
JV 747	28.5	31.2	31.0	34.0	31.5	33.0
JE 78	28.2	30.5	30.5			
JE 95				28.5	29.0	31.5
JV 751	29.5	33.0	31.0			
JV 745				35.0	34.5	35.0

APPENDIX 7 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	29.5	29.5	30.5	32.0	31.0	31.0
JV 738	36.0	30.0	32.5	33.0	(34.2)	(33.2)
JE 154	32.0	32.0	34.5	35.5	36.0	32.0
JV 741	30.5	33.0	(30.7)	(31.0)	(32.0)	(31.0)
JE 156	31.0	31.0	33.5	35.0	35.0	32.0
JV 732	32.5	32.5	33.5	33.0	35.0	34.0
JE 188	33.0	35.5	34.5	36.0	34.0	32.0
JV 744	27.0	29.5	29.5	32.0	29.0	27.0
JE 56	28.5	32.0	29.5	30.0	31.0	30.0
JV 753	32.0	32.0	33.0	(31.4)	32.0	30.0
JE 165	31.0	30.0	32.0	33.0	34.0	34.0
JV 736	29.0	30.0	30.5	32.0	31.0	29.0
JE 180	29.5	28.0	29.5	33.0	33.0	30.0
JV 746	27.0	30.0	28.5	29.0	30.0	33.0
JE 121	36.0	32.0	32.0	33.0	35.0	33.0
JV 737	38.5	33.0	34.5	33.0	40.0	35.0
JE 85	34.5	35.0	34.0	36.0	33.0	31.0
JV 747	30.0	33.5	(32.5)	(32.8)	(33.8)	(32.8)
JE 95	33.0	30.5	27.0	29.0	29.0	28.0
JV 745	35.5	32.5	34.5	36.0	36.0	38.0

APPENDIX 8 Individual results for the red cell count of the experimental Jersey animals.

Cow No.	Sample No.					
	1	2	3	4	5	6
JE 80	5.587	5.540	5.632	5.590	5.525	6.055
JV 738	6.112	6.272	6.007	6.445	5.665	6.650
JE 154	6.397	6.405	6.500	6.050	6.895	6.205
JV 741	4.585	5.075	4.322	4.955	4.785	4.970
JE 156	5.900	5.637	5.115	5.390	5.490	5.350
JV 732	6.037	5.560	5.785	5.650	6.305	6.185
JE 188	5.365	5.700	4.930	5.460	5.540	5.295
JV 744	4.805	4.667	4.290	3.985	4.200	4.455
JE 56	5.307	5.697	4.937	5.620	5.230	5.825
JV 753	5.367	5.722	5.047	5.680	6.085	5.590
JE 165	5.770	6.020	5.790	5.645	5.625	5.440
JV 736	5.010	5.140	4.780	5.010	5.130	5.300
JE 180	5.620	5.720	5.502	5.620	6.125	6.195
JV 746	5.732	6.665	5.642	5.710	6.250	6.495
JE 161	6.650	5.382	5.520			
JE 121				5.370	5.630	5.340
JV 737	5.287	6.342	6.737	5.640	5.585	5.995
JE 183	6.760	7.480	6.545			
JE 85				5.625	6.225	5.420
JV 747	5.640	5.680	5.575	6.005	5.800	6.195
JE 78	5.490	4.902	5.122			
JE 95				5.910	5.375	5.180
JV 751	5.562	5.742	4.980			
JV 745				6.285	5.775	5.705

APPENDIX 8 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	5.300	5.570	5.500	5.705	5.670	6.205
JV 738	6.900	6.255	5.590	6.040	(5.874)	(6.441)
JE 154	5.770	5.025	5.885	6.580	5.875	5.160
JV 741	5.000	4.460	(4.817)	(4.630)	(4.440)	(5.007)
JE 156	5.545	5.190	6.290	4.460	5.535	5.610
JV 732	6.475	6.000	5.670	5.600	5.445	5.970
JE 188	5.850	6.300	5.860	5.750	5.570	6.045
JV 744	4.585	4.870	4.930	5.235	5.325	5.230
JE 56	5.525	5.085	5.890	5.595	4.535	5.025
JV 753	6.450	6.330	6.910	(5.765)	5.030	5.875
JE 165	5.375	5.235	5.815	4.335	5.350	5.765
JV 736	5.085	5.400	5.570	4.980	4.390	5.005
JE 180	6.045	5.135	5.880	5.790	4.880	6.470
JV 746	5.485	5.705	5.965	5.785	4.875	5.765
JE 121	5.870	5.385	5.040	5.300	5.230	5.225
JV 737	5.845	5.330	5.435	4.675	5.500	5.980
JE 85	6.285	5.950	5.020	5.520	5.515	4.760
JV 747	5.535	5.490	(5.788)	(5.601)	(5.411)	(5.978)
JE 95	5.570	5.150	4.180	4.830	4.050	4.655
JV 745	5.515	5.920	5.470	5.960	6.080	6.790

APPENDIX 9 Individual results for the white cell count of the experimental Jersey animals.

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	9.962	9.412	9.687	8.450	10.150	9.650
JV 738	8.875	9.312	7.762	8.600	7.775	6.825
JE 154	13.000	10.375	11.462	9.975	11.100	10.425
JV 741	6.775	7.637	6.762	6.325	8.000	7.025
JE 156	11.137	8.000	10.012	10.850	12.000	9.575
JV 732	11.100	11.625	13.775	10.550	11.475	15.675
JE 188	8.750	13.237	13.962	12.750	11.825	10.350
JV 744	9.550	7.087	8.412	9.225	8.100	7.425
JE 56	10.137	10.550	8.775	7.150	9.825	9.900
JV 753	9.038	8.725	7.300	9.350	9.175	10.025
JE 165	9.087	9.875	8.700	10.950	6.900	9.450
JV 736	6.937	8.012	6.225	7.825	5.950	7.625
JE 180	10.225	7.750	9.250	8.475	11.625	9.625
JV 746	9.950	9.350	8.200	6.600	9.650	9.450
JE 161	10.200	11.462	12.587			
JE 121				10.450	11.525	11.075
JV 737	11.500	12.350	11.162	10.750	12.975	8.200
JE 133	9.562	8.737	8.475			
JE 85				14.800	12.750	12.075
JV 747	9.275	9.412	11.300	10.525	10.175	9.625
JE 78	6.025	12.400	8.537			
JE 95				10.250	8.525	7.250
JV 751	8.225	7.562	10.987			
JV 745				7.000	7.250	5.325

APPENDIX 9 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	11.425	9.600	8.600	11.525	8.825	9.100
JV 738	7.225	5.700	6.625	5.800	(7.586)	(7.429)
JE 154	11.975	9.050	11.025	14.975	8.175	8.625
JV 741	8.600	8.500	(8.196)	(7.573)	(7.776)	(7.619)
JE 156	13.800	12.275	9.950	12.550	6.325	9.500
JV 732	12.850	12.600	14.875	13.125	13.900	13.650
JE 188	11.425	11.400	12.250	9.050	9.175	8.450
JV 744	8.275	9.475	10.200	10.800	10.425	10.200
JE 56	12.275	12.950	12.800	11.500	14.800	13.200
JV 753	9.375	11.175	10.950	(9.382)	9.000	9.700
JE 165	10.075	9.975	12.375	9.700	9.100	9.050
JV 736	6.300	7.175	6.150	8.000	7.750	6.550
JE 180	8.750	11.650	9.800	9.400	11.900	11.025
JV 746	8.325	8.100	9.100	8.150	8.350	7.850
JE 121	9.125	10.800	7.550	9.075	7.050	9.500
JV 737	9.700	9.400	10.950	10.150	9.575	10.600
JE 85	10.300	12.875	14.200	11.600	9.150	10.225
JV 747	13.150	9.550	(10.995)	(10.370)	(10.574)	(10.417)
JE 95	10.575	9.675	8.675	10.000	9.925	11.100
JV 745	8.600	7.950	8.350	6.800	7.250	6.600

APPENDIX 10 Individual results for the total lymphocyte count of the experimental Jersey animals.

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	7.183	6.391	6.558	5.915	6.790	7.305
JV 738	6.568	7.226	4.409	6.140	5.520	5.446
JE 154	9.828	7.242	7.909	7.122	7.337	6.630
JV 741	5.359	4.964	4.416	3.365	4.851	4.524
JE 156	7.529	5.640	6.147	6.738	6.936	6.176
JV 732	8.025	8.951	9.946	8.039	8.847	10.173
JE 188	6.510	6.844	7.693	8.479	6.019	6.572
JV 744	6.026	4.592	5.291	5.876	5.937	5.175
JE 56	7.309	7.501	6.669	3.997	6.268	6.544
JV 753	7.113	5.863	5.723	6.059	6.211	7.318
JE 165	5.661	5.441	5.507	6.252	3.843	5.065
JV 736	5.224	5.945	5.341	5.102	4.623	5.009
JE 180	8.252	6.409	7.520	5.848	7.428	7.305
JV 746	6.935	5.675	5.059	4.006	6.099	6.435
JE 161	6.079	7.049	7.036			
JE 121				6.594	6.512	7.199
JV 737	8.027	8.744	7.233	8.439	9.173	6.191
JE 133	7.334	6.308	5.466			
JE 85				10.049	7.586	8.827
JV 747	6.344	4.857	5.910	6.452	6.532	6.333
JE 78	4.470	9.027	5.105			
JE 95				7.073	5.030	5.119
JV 751	5.815	4.454	7.065			
JV 745				3.710	4.285	3.882

APPENDIX 10 (Cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	7.906	6.739	6.373	6.892	6.248	6.479
JV 738	5.195	4.172	4.922	4.315	(5.492)	(5.245)
JE 154	7.245	5.910	6.174	8.835	4.930	4.752
JV 741	5.917	5.278	(5.317)	(4.832)	(4.946)	(4.709)
JE 156	7.493	7.696	6.000	5.848	4.206	6.336
JV 732	9.740	8.681	9.758	9.660	9.744	10.306
JE 188	7.095	6.840	7.877	6.616	6.000	6.236
JV 744	6.214	6.045	6.844	7.128	6.234	7.079
JE 56	7.930	7.835	6.656	7.762	10.641	8.804
JV 753	6.356	7.722	7.490	(6.642)	6.219	6.722
JE 165	5.854	4.778	5.408	5.839	5.387	5.493
JV 736	4.278	4.786	4.041	6.160	6.115	4.447
JE 180	6.457	7.934	6.419	6.514	9.687	8.522
JV 746	5.070	4.649	5.369	5.208	5.002	4.278
JE 121	5.648	6.890	4.107	6.235	4.639	6.042
JV 737	6.926	6.552	7.851	7.866	7.784	7.261
JE 85	7.200	8.729	10.423	8.746	6.716	5.624
JV 747	8.100	5.357	(6.480)	(6.222)	(6.323)	(6.042)
JE 95	6.567	7.759	6.098	6.200	6.203	7.237
JV 745	5.745	4.142	4.492	3.216	4.140	3.874

APPENDIX 11 Individual results for the total neutrophil count of the experimental Jersey animals

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	1.146	1.327	2.780	0.963	1.320	1.592
JV 738	1.163	1.006	2.003	1.479	1.026	0.601
JE 154	2.145	1.567	2.762	1.925	2.387	1.804
JV 741	0.786	1.634	1.508	1.569	2.214	1.019
JE 156	1.927	1.536	2.453	2.485	3.480	1.905
JV 732	1.743	1.999	2.300	1.255	1.457	3.010
JE 188	1.260	5.665=	5.934	2.996	4.529	2.753
JV 744	2.674	1.517	1.741	1.974	1.158	0.765
JE 56	1.095	1.783	1.719	1.938	2.515	2.059
JV 753	1.085	2.015	1.307	1.861	2.009	1.373
JE 165	1.990	2.558	1.931	3.548	1.711	3.024
JV 736	1.152	0.849	0.629	1.628	0.690	1.296
JE 180	0.828	0.729	1.239	1.831	3.116	1.357
JV 746	1.891	2.141	2.034	1.927	2.268	1.956
JE 161	2.133	3.473	3.033			
JE 121				2.017	2.881	1.994
JV 737	1.829	2.631	3.203	1.301	2.297	0.590
JE 133	1.052	1.398	2.076			
JE 85				2.028	2.474	1.183
JV 747	1.530	1.977	3.831	2.505	1.709	1.858
JE 78	0.506	1.500	1.579			
JE 95				1.896	2.558	1.124
JV 751	1.694	2.306	3.626			
JV 745				1.505	1.689	0.580

APPENDIX 11 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	1.805	1.786	0.963	3.273	0.715	0.337
JV 738	1.004	0.490	0.470	0.690	(0.865)	(0.966)
JE 154	2.587	2.199	3.087	3.639	1.766	2.070
JV 741	1.410	1.776	(1.735)	(1.378)	(1.384)	(1.486)
JE 156	3.850	2.627	1.701	3.840	1.113	1.995
JV 732	2.454	2.444	3.064	1.956	2.141	2.020
JE 188	2.765	2.907	3.062	1.133	2.138	1.589
JV 744	0.827	1.801	1.561	2.192	2.856	1.561
JE 56	3.216	3.548	3.712	1.024	2.264	2.204
JV 753	2.147	2.045	2.113	1.632	1.449	1.892
JE 165	2.045	3.172	3.391	1.581	2.275	1.520
JV 736	1.128	1.213	1.205	0.536	0.783	1.087
JE 180	1.444	2.889	1.980	1.410	1.654	1.775
JV 746	2.547	1.766	2.047	1.899	2.104	1.994
JE 121	2.336	2.668	2.122	1.933	1.079	1.938
JV 737	1.562	1.551	2.048	1.218	0.862	1.940
JE 85	1.483	1.841	1.775	1.670	1.711	2.495
JV 747	3.011	2.282	(2.503)	(2.167)	(2.168)	(2.312)
JE 95	1.999	1.500	1.388	2.820	2.580	2.597
JV 745	1.625	1.765	2.171	1.931	1.262	1.459

APPENDIX 12 Individual results for the total eosinophil count of the experimental Jersey animals.

Cow No.	Sample Number					
	1	2	3	4	5	6
JE 80	1.295	1.525	0.184	1.352	1.868	0.598
JV 738	0.888	0.968	1.125	0.774	1.011	0.621
JE 154	0.767	1.432	0.481	0.678	1.154	1.564
JV 741	0.413	0.764	0.636	1.259	1.611	1.061
JE 156	1.348	0.640	0.841	1.421	1.236	1.254
JV 732	1.066	0.349	1.212	0.886	1.033	2.241
JE 188	0.753	0.437	0.126	0.995	0.922	0.611
JV 744	0.573	0.787	1.195	1.125	0.794	1.225
JE 56	1.459	1.139	0.202	0.944	0.737	1.129
JV 753	0.732	0.567	0.102	1.187	0.669	1.103
JE 165	1.081	1.649	1.061	0.931	1.187	1.143
JV 736	0.423	1.074	0.137	0.931	0.452	1.151
JE 180	0.808	0.496	0.342	0.661	0.721	0.587
JV 746	0.955	1.206	0.951	0.508	0.965	0.851
JE 161	1.642	0.745	2.089			
JE 121				1.599	1.878	1.528
JV 737	1.219	0.827	0.479	0.828	0.986	1.246
JE 133	0.832	0.795	0.669			
JE 85				2.368	2.359	1.799
JV 747	1.141	2.325	1.175	1.295	1.709	1.001
JE 78	0.952	1.624	1.699			
JE 95				0.984	0.784	0.812
JV 751	0.436	0.476	0.077			
JV 745				1.568	0.964	0.708

APPENDIX 12 (cont.)

Cow No.	Sample Number					
	7	8	9	10	11	12
JE 80	1.554	0.989	1.075	1.187	1.756	2.157
JV 738	0.896	0.963	1.073	0.621	(1.138)	(1.092)
JE 154	1.856	0.796	1.544	2.276	1.341	1.708
JV 741	1.075	1.360	(1.220)	(1.166)	(1.291)	(1.242)
JE 156	2.263	1.706	2.169	2.648	0.898	1.026
JV 732	0.424	1.323	1.666	1.391	1.793	1.078
JE 188	1.360	1.391	0.968	0.525	0.844	0.380
JV 744	1.125	1.601	1.530	1.393	1.251	1.408
JE 56	0.970	1.269	2.240	1.449	1.643	2.059
JV 753	0.562	1.229	1.204	(0.938)	1.179	0.970
JE 165	1.985	1.716	3.341	2.173	1.210	1.891
JV 736	0.800	0.997	0.769	1.160	0.783	0.852
JE 180	0.717	0.664	1.196	1.335	0.369	0.573
JV 746	0.508	1.539	1.474	0.823	1.169	1.436
JE 121	0.985	1.037	1.200	0.789	1.184	1.340
JV 737	0.999	1.203	0.799	0.954	0.833	1.219
JE 85	1.318	2.086	1.718	0.986	0.631	1.912
JV 747	1.815	1.623	(1.983)	(1.742)	(1.903)	(1.844)
JE 95	1.777	0.329	0.980	0.880	1.002	1.088
JV 745	1.041	1.884	1.528	1.489	1.718	1.188

APPENDIX 13 Individual haemoglobin results for the KDF animals.

NO.	DENMARK	1	2	3	4	5	6
(1)	12.2	13.1	10.3	10.2	10.3	11.0	11.3
(2)	12.7	12.6	10.6	12.6	12.2	11.7	11.3
(3)	14.5	12.9	11.2	11.5	12.0	12.8	12.6
(4)	12.3	13.0	10.6	12.8	12.9	12.9	12.0
(5)	13.8	13.3	10.7	10.5	11.1	11.2	10.7
(6)	12.6	12.1	11.3	12.9	12.4	11.5	10.9
(7)	13.0	14.5	11.8	13.6	13.4	13.1	12.3
(8)	12.3	12.6	11.5	11.8	11.6	(12.1)	(11.3)
(9)	13.2	13.1	11.7	11.3	11.2	11.7	11.2
(10)	10.8	13.2	10.2	11.1	10.7	11.2	10.8
(11)	13.5	13.9	11.4	11.1	11.8	12.3	11.2
(12)	9.4	12.7	10.2	10.5	11.1	11.3	10.6
(13)	12.7	12.3	10.1	10.7	11.2	11.6	11.8
(14)	14.1	13.0	11.9	11.0	12.3	12.8	12.2
(15)	13.1	12.0	10.8	10.9	12.1	12.8	11.5
(16)	11.1	12.9	10.4	12.7	11.5	12.4	11.0
(17)	12.2	13.1	11.9	13.3	12.8	13.5	11.5
(18)	13.2	13.2	12.1	12.0	12.1	12.2	11.1
(19)	12.6	13.4	11.8	13.0	12.2	12.8	11.6
(20)	13.5	12.6	12.1	12.8	12.9	12.6	11.2
(21)	11.8	14.1	11.6	12.4	13.9	13.6	12.6
(22)	12.5	12.8	11.5	12.1	13.0	12.7	12.6
(23)	12.5	11.4	10.3	10.3	10.0	11.6	10.7
(24)	13.8	14.3	11.8	11.2	12.7	11.0	10.0

APPENDIX 14 Individual packed cell volume results for the KDF animals.

NO.	DENMARK	1	2	3	4	5	6
(1)	37.0	41.5	35.0	33.0	32.0	34.0	36.0
(2)	38.0	37.5	35.0	35.0	36.0	35.0	35.0
(3)	43.0	40.0	37.0	37.0	36.0	38.0	38.0
(4)	38.0	39.0	33.0	37.0	37.0	35.0	36.0
(5)	43.0	40.5	35.0	33.5	35.0	34.0	35.0
(6)	38.5	35.5	35.0	38.0	36.0	34.0	34.0
(7)	37.5	42.5	38.0	39.0	38.0	40.0	37.0
(8)	36.5	36.0	37.0	36.0	35.0	(35.0)	(35.0)
(9)	42.0	38.0	36.0	34.5	33.0	35.0	36.0
(10)	35.0	37.0	34.0	32.5	33.0	33.0	33.0
(11)	38.0	41.0	35.0	34.5	37.0	36.0	35.0
(12)	28.0	37.5	32.0	33.0	33.0	33.0	32.0
(13)	39.5	38.0	33.0	34.5	34.0	35.0	35.0
(14)	42.5	39.0	35.0	33.5	35.0	37.0	38.0
(15)	39.0	36.0	34.0	34.0	35.0	36.0	34.0
(16)	35.0	40.5	33.0	37.0	37.0	37.0	35.0
(17)	35.0	41.0	37.0	38.0	38.0	39.0	36.0
(18)	39.0	41.0	38.0	37.0	36.0	34.0	34.0
(19)	29.0	42.0	37.0	36.0	37.0	38.0	38.0
(20)	41.0	40.0	38.0	38.0	38.0	37.0	35.0
(21)	36.0	41.5	38.0	36.0	38.0	38.0	38.0
(22)	38.5	39.5	36.0	37.0	38.0	38.0	38.0
(23)	36.0	35.0	33.0	33.0	30.0	33.0	34.0
(24)	37.0	41.5	36.0	36.0	37.0	31.0	33.0

APPENDIX 15 Individual red cell count results for the KDF animals.

NO.	DENMARK	1	2	3	4	5	6
(1)	5.870	5.685	5.190	5.220	4.965	5.625	6.190
(2)	7.530	5.950	5.755	6.525	7.035	7.055	6.450
(3)	6.270	5.760	5.940	6.025	6.190	5.380	6.590
(4)	6.340	5.915	5.450	6.835	6.785	7.165	6.865
(5)	7.440	7.110	6.520	5.825	6.955	6.375	7.160
(6)	6.920	5.720	5.740	6.910	6.685	5.665	6.305
(7)	6.300	5.850	6.165	6.200	6.670	7.435	6.290
(8)	6.440	6.155	6.690	6.305	5.625	(6.374)	(6.538)
(9)	7.380	6.640	6.310	6.035	6.200	6.090	6.130
(10)	5.460	5.480	5.675	5.765	5.870	6.100	6.530
(11)	7.150	5.560	6.165	6.095	5.995	5.400	6.430
(12)	4.140	5.125	5.105	5.895	6.335	6.530	5.785
(13)	6.660	6.015	6.085	6.110	6.080	6.120	6.930
(14)	6.910	6.100	6.000	5.805	6.445	6.265	6.585
(15)	7.220	6.575	6.660	6.050	7.110	6.900	7.070
(16)	6.140	7.295	6.600	6.905	6.955	6.705	6.325
(17)	6.610	7.060	6.250	6.015	7.155	7.615	6.910
(18)	5.930	6.420	6.020	5.950	5.855	6.285	6.445
(19)	6.340	6.565	6.130	6.225	6.335	7.465	7.125
(20)	6.080	5.370	6.235	5.710	6.125	5.160	5.400
(21)	5.880	5.470	6.00	5.650	5.960	6.140	5.440
(22)	7.000	5.900	6.050	5.645	6.865	5.875	7.540
(23)	7.770	6.075	5.640	5.330	5.200	5.760	6.420
(24)	7.110	6.830	5.765	6.305	6.340	5.790	5.775

APPENDIX 16 Individual white cell count results for the KDF animals.

NO.	DENMARK	1	2	3	4	5	6
(1)	3.800	5.100	6.625	5.625	10.750	8.950	11.125
(2)	8.500	7.875	11.375	9.950	7.900	10.525	13.025
(3)	5.800	6.325	8.025	9.550	11.325	6.425	13.425
(4)	5.800	5.425	9.200	9.450	10.550	12.225	6.325
(5)	6.700	8.600	10.275	9.550	7.175	10.675	11.375
(6)	7.800	6.650	9.225	10.325	10.300	6.700	8.925
(7)	6.600	5.550	10.200	10.275	9.150	8.475	8.025
(8)	9.000	8.100	14.875	5.325	14.875	(11.059)	(11.841)
(9)	9.400	9.250	11.650	10.200	10.800	7.125	9.400
(10)	8.000	5.150	6.775	7.850	6.200	8.425	10.550
(11)	8.100	6.325	9.900	10.275	9.875	6.225	8.925
(12)	3.500	5.825	8.450	7.450	6.400	9.875	8.350
(13)	7.900	6.000	9.050	6.450	7.875	7.850	9.700
(14)	3.700	5.050	10.525	6.500	7.725	7.225	7.800
(15)	5.500	5.625	8.800	9.400	9.425	11.775	13.175
(16)	8.800	5.550	8.400	6.550	9.050	13.475	8.525
(17)	7.900	7.725	8.575	9.675	9.900	8.675	8.550
(18)	6.300	7.875	8.875	10.625	13.500	10.275	9.225
(19)	7.000	6.650	7.100	8.500	9.050	9.475	8.600
(20)	8.800	4.800	9.950	8.075	8.450	7.775	7.375
(21)	8.000	5.650	9.750	9.025	7.975	7.325	6.650
(22)	6.000	7.025	6.800	10.725	13.300	7.075	8.925
(23)	11.900	7.350	10.325	12.550	9.450	9.225	10.075
(24)	9.300	5.500	6.975	8.925	8.500	4.275	10.000

APPENDIX 17 Individual total lymphocyte count results for the KDF animal.

NO.	DENMARK	1	2	3	4	5	6
(1)	2.679	3.208	4.001	3.420	4.698	7.518	8.674
(2)	5.440	4.174	7.621	4.259	5.310	8.220	10.081
(3)	3.538	4.307	5.561	7.993	5.017	5.333	10.619
(4)	3.016	2.349	4.674	5.746	5.412	8.179	5.003
(5)	4.020	5.538	6.309	5.396	4.262	8.316	8.304
(6)	5.655	5.460	5.498	7.651	6.654	5.213	6.167
(7)	3.432	3.519	6.253	6.340	4.895	5.704	5.866
(8)	3.240	3.945	9.803	4.452	6.694	(7.548)	(8.069)
(9)	6.063	7.169	7.899	6.130	9.137	4.781	6.975
(10)	5.120	3.399	4.600	4.223	4.613	5.577	7.796
(11)	3.564	3.270	5.386	5.518	3.535	3.592	5.667
(12)	2.695	2.988	4.031	4.634	4.550	6.754	6.680
(13)	5.095	3.906	5.520	5.418	5.827	6.241	7.391
(14)	2.793	4.126	7.494	4.953	6.087	5.469	5.390
(15)	3.190	2.824	6.037	6.808	6.173	9.926	9.881
(16)	4.312	2.392	4.889	4.592	5.511	10.793	6.172
(17)	3.673	5.106	4.802	6.492	6.148	6.888	5.387
(18)	4.252	5.087	5.902	6.726	9.356	8.539	6.983
(19)	3.500	4.342	4.594	4.726	5.620	6.746	5.848
(20)	4.576	3.230	4.895	5.539	4.783	5.893	6.276
(21)	5.240	3.881	7.322	5.623	5.064	5.406	5.260
(22)	3.150	3.344	3.808	4.408	7.714	4.875	8.306
(23)	5.117	3.837	4.533	7.367	4.007	5.720	5.189
(24)	2.557	2.415	5.154	4.392	5.754	3.553	7.310

APPENDIX 18 Individual total neutrophil count results for the KDF anima

NO.	DENMARK	1	2	3	4	5	6
(1)	0.760	1.596	1.822	1.603	5.644	1.011	1.880
(2)	2.295	2.890	1.513	3.970	1.967	1.337	2.240
(3)	1.682	1.682	1.709	1.280	5.334	0.411	1.973
(4)	2.146	2.398	2.788	2.325	4.916	2.494	0.886
(5)	1.943	2.030	3.237	3.400	2.160	1.655	1.957
(6)	1.959	0.984	3.026	2.179	2.853	1.199	2.437
(7)	2.442	1.304	2.091	2.702	3.468	2.178	2.613
(8)	5.310	3.143	4.388	0.623	7.512	(3.563)	(3.504)
(9)	3.196	1.767	3.029	2.632	1.080	1.824	2.077
(10)	2.160	1.241	0.915	2.645	1.042	2.418	1.635
(11)	2.997	2.176	3.148	3.278	4.770	2.048	1.937
(12)	0.577	1.648	3.870	2.280	1.350	2.321	1.303
(13)	2.014	1.224	2.543	0.677	1.764	1.115	1.736
(14)	0.647	0.505	1.947	1.137	1.205	1.387	1.256
(15)	1.595	1.001	2.200	1.814	2.036	1.578	2.464
(16)	4.136	1.393	2.402	1.605	3.285	1.806	1.927
(17)	3.910	1.213	1.912	1.712	2.485	1.553	1.915
(18)	1.638	1.567	2.041	3.102	3.307	0.688	1.762
(19)	2.940	1.669	1.775	3.026	2.715	2.274	2.202
(20)	3.036	0.888	4.219	1.986	2.450	1.112	0.656
(21)	1.760	1.141	1.794	2.617	2.113	1.088	1.044
(22)	2.310	2.227	1.707	4.279	4.322	1.627	1.977
(23)	4.284	1.610	3.727	2.635	4.337	2.315	3.335
(24)	6.370	1.914	1.158	3.864	2.371	0.286	0.650

APPENDIX 19 Individual total eosinophil count results for the KDF animals.

NO.	DENMARK	1	2	3	4	5	6
(1)	0.361	0.209	0.715	0.501	0.226	0.412	0.656
(2)	0.765	0.567	2.104	1.473	0.521	0.979	0.703
(3)	0.580	0.234	0.570	0.162	0.736	0.681	0.832
(4)	0.638	0.559	1.573	1.049	0.042	1.553	0.443
(5)	0.737	0.851	0.555	0.420	0.624	0.705	1.186
(6)	0.195	0.106	0.553	0.289	0.670	0.188	0.321
(7)	0.726	0.655	1.744	0.997	0.613	0.593	0.546
(8)	0.450	0.761	0.431	0.176	0.223	(0.294)	(0.396)
(9)	0.141	0.157	0.524	1.183	0.184	0.520	0.348
(10)	0.720	0.417	1.186	0.746	0.428	0.430	1.129
(11)	1.539	0.721	1.069	1.151	1.402	0.585	1.312
(12)	0.227	0.885	0.346	0.395	0.352	0.800	0.367
(13)	0.790	0.648	0.887	0.258	0.189	0.502	0.563
(14)	0.259	0.283	1.000	0.221	0.317	0.361	1.147
(15)	0.715	1.659	0.370	0.273	1.037	0.271	0.839
(16)	0.352	1.587	0.966	0.242	0.127	0.876	0.426
(17)	0.316	1.213	1.715	1.180	1.030	0.234	1.248
(18)	0.409	0.992	0.754	0.563	0.499	1.048	0.470
(19)	0.560	0.492	0.540	0.629	0.534	0.455	0.550
(20)	1.188	0.547	0.736	0.412	0.955	0.770	0.443
(21)	1.000	0.537	0.487	0.704	0.694	0.901	0.339
(22)	0.540	1.370	1.163	1.855	0.984	0.573	1.143
(23)	2.499	1.727	1.858	2.196	0.983	1.190	1.552
(24)	0.372	1.045	0.580	0.464	0.255	0.436	1.030

(8)

APPENDIX 20 Individual haemoglobin results for the EDF animals.

NO.	DENMARK	1	2	3	4	5	
(25)	11.1	12.4	11.7	10.3	10.4	10.8	
(26)	10.6	11.4	11.2	10.9	11.2	10.9	
(27)	11.4	10.1	9.8	9.4	9.8	10.0	
(28)	11.3	11.9	10.7	111.1	10.6	10.5	
(29)	12.7	12.5	11.9	13.4	11.5	11.6	
(30)	12.1	11.0	12.3	11.2	11.6	11.9	
(31)	13.0	11.4	11.6	12.7	11.2	10.8	
(32)	11.8	11.3	10.0	10.1	10.5	10.8	
(33)	13.6	12.0	12.1	12.2	12.0	13.0	
(34)	10.5	11.2	10.5	10.9	9.9	10.4	
(35)	12.0	11.4	12.0	12.3	12.0	12.1	
(36)	12.5	11.4	11.3	12.7	12.0	12.0	
(37)	11.2	10.7	10.6	10.7	10.3	9.4	
(38)	11.1	11.0	11.3	11.0	10.3	10.4	
(39)	11.8	11.9	11.3	12.2	(11.4)	(11.5)	
(40)	12.7	10.9	9.7	9.7	8.9	9.2	
Total	189.4	182.5	178.0	180.8	173.6	175.3	890.2

APPENDIX 21 Individual packed cell volume results for the EDF animals.

NO.	DENMARK	1	2	3	4	5	6
(25)	35.0	36.5	32.0	30.0	30.0	33.0	
(26)	34.0	34.5	34.0	33.0	34.0	34.0	
(27)	34.0	32.0	29.0	28.0	30.0	28.0	
(28)	40.0	36.5	34.0	35.0	34.0	34.0	
(29)	35.0	35.0	34.0	37.0	34.0	35.0	
(30)	35.5	32.0	36.0	32.0	34.0	35.0	
(31)	40.0	35.5	36.0	38.0	35.0	34.0	
(32)	38.0	34.0	29.0	28.0	30.0	33.0	
(33)	42.0	37.5	37.0	36.0	37.0	38.0	
(34)	32.0	31.0	33.0	33.0	32.0	33.0	
(35)	36.5	35.5	37.0	37.0	35.0	37.0	
(36)	38.0	33.0	35.0	37.0	36.0	34.0	
(37)	36.0	35.0	32.0	33.0	31.0	30.0	
(38)	38.0	38.0	35.0	33.0	33.0	32.0	
(39)	38.5	37.5	34.0	37.0	(35.1)	(35.6)	
(40)	40.5	36.0	30.0	30.0	28.0	30.0	
Total	593.0	559.5	537.5	537.0	528.1	535.6	2697.7

APPENDIX 22 Individual red cell count results for the EDF animals.

NO.	DENMARK	1	2	3	4	5	6
(25)	6.890	6.950	8.140	6.730	7.030	6.765	
(26)	4.570	7.310	7.205	7.115	7.195	5.900	
(27)	5.440	6.380	6.440	6.780	5.920	6.250	
(28)	6.380	6.300	6.960	7.610	6.500	6.255	
(29)	8.710	7.385	7.500	8.935	6.835	7.195	
(30)	5.960	7.115	7.645	6.570	7.065	6.745	
(31)	6.170	7.250	8.070	8.580	8.075	7.255	
(32)	6.070	6.580	7.140	6.785	6.905	6.750	
(33)	7.420	7.645	7.150	7.360	7.030	6.350	
(34)	6.540	6.975	6.985	7.675	6.820	6.340	
(35)	6.230	6.320	7.590	7.585	7.410	7.895	
(36)	6.690	6.060	6.365	7.160	7.080	6.565	
(37)	4.770	8.455	8.225	7.855	7.445	6.435	
(38)	6.800	7.345	6.880	6.480	6.340	5.865	
(39)	6.650	7.720	6.405	7.240	(6.799)	(6.450)	
(40)	5.820	9.040	6.475	7.345	6.325	6.180	
Total	101.160	114.830	115.175	117.805	110.774	105.195	

APPENDIX 23 Individual white cell count results for the EDF animals.

NO.	DENMARK	1	2	3	4	5	6
(25)	9.400	8.825	8.000	9.400	11.350	8.800	
(26)	8.200	9.375	11.625	13.550	8.700	10.425	
(27)	7.100	6.775	6.050	5.950	5.700	7.850	
(28)	5.500	5.875	5.900	7.325	8.600	7.075	
(29)	8.500	11.750	8.175	14.875	10.775	10.825	
(30)	11.500	8.300	10.800	10.400	12.300	14.525	
(31)	15.700	12.750	11.050	13.175	11.550	12.325	
(32)	10.400	7.550	8.400	8.750	10.550	8.050	
(33)	8.000	11.850	7.225	9.650	11.825	9.525	
(34)	7.800	8.700	5.900	8.050	11.525	10.325	
(35)	8.000	11.000	10.900	11.900	9.325	12.400	
(36)	7.400	8.125	9.150	6.550	8.050	10.025	
(37)	8.800	12.275	6.050	10.300	10.375	9.825	
(38)	15.400	15.775	11.025	13.725	17.775	12.075	
(39)	9.300	9.075	7.925	9.600	(9.351)	(9.191)	
(40)	8.200	17.575	10.125	9.975	5.550	8.000	
Total	149.200	165.175	138.300	163.175	163.301	160.741	790.692

APPENDIX 24 Individual total lymphocyte count results for the EDF animals.

NO.	DENMARK	1	2	3	4	5
(25)	5.593	4.554	4.520	4.841	8.342	5.553
(26)	5.453	5.850	7.452	9.322	5.698	7.621
(27)	4.402	3.807	4.459	4.427	4.246	5.997
(28)	4.345	3.813	3.522	4.695	5.874	5.023
(29)	5.907	7.485	5.722	10.665	7.112	6.814
(30)	7.762	5.536	8.154	7.322	8.942	10.676
(31)	10.205	7.318	7.724	9.644	9.332	10.254
(32)	5.980	4.568	5.888	6.457	7.068	6.054
(33)	4.600	6.023	4.927	7.295	8.940	6.658
(34)	5.460	6.116	4.083	5.997	8.413	6.887
(35)	4.000	8.151	7.641	7.854	7.469	8.705
(36)	5.032	6.175	6.817	5.043	7.132	7.799
(37)	5.984	8.421	4.465	7.890	9.410	7.496
(38)	8.701	8.976	7.905	9.209	10.967	7.837
(39)	5.719	5.790	5.310	7.258	(7.237)	(7.000)
(40)	3.198	6.046	4.242	6.145	3.546	5.560
Total	92.341	98.629	92.831	114.064	119.728	115.934

APPENDIX 25 Individual total neutrophil count results for the EDF animals.

NO.	DENMARK	1	2	3	4	5
(25)	3.619	3.768	3.352	4.315	2.122	2.306
(26)	2.542	2.766	3.697	3.509	2.314	2.210
(27)	2.307	2.723	1.204	1.386	1.009	1.374
(28)	1.100	1.927	2.148	2.476	1.892	1.769
(29)	2.337	3.783	2.240	2.187	1.228	2.715
(30)	2.875	2.407	2.041	2.891	2.398	3.254
(31)	5.495	5.100	2.630	3.294	1.917	1.282
(32)	3.900	2.771	1.915	1.907	2.743	1.457
(33)	2.960	4.672	2.023	1.814	2.672	2.229
(34)	1.950	2.027	1.239	1.465	2.489	2.395
(35)	3.760	2.464	2.845	2.785	1.315	2.864
(36)	2.109	1.641	1.363	1.317	0.708	1.464
(37)	2.728	3.241	1.325	2.214	0.612	1.975
(38)	6.468	5.521	2.679	4.145	6.328	3.731
(39)	3.301	2.768	2.013	1.642	(1.382)	(1.500)
(40)	5.002	9.930	5.113	1.935	1.598	2.088
Total	52.453	57.509	37.827	39.282	32.727	34.613

APPENDIX 26 Individual total eosinophil count results for the EDF animals.

NO.	DENMARK	1	2	3	4	5
(25)	0.188	0.274	0	0.244	0.885	0.942
(26)	0.205	0.609	0.256	0.718	0.687	0.594
(27)	0.390	0.108	0.278	0.137	0.445	0.479
(28)	0.055	0.053	0.148	0.154	0.843	0.283
(29)	0.255	0.235	0.147	2.023	2.435	0.795
(30)	0.862	0.274	0.616	0.198	0.959	0.596
(31)	0	0.089	0.696	0.237	0.300	0.789
(32)	0.520	0.068	0.277	0.385	0.728	0.531
(33)	0.440	0.584	0.152	0.540	0.225	0.629
(34)	0.390	0.444	0.690	0.588	0.627	1.053
(35)	0.240	0.154	0.272	1.261	0.550	0.818
(36)	0.259	0.130	0.970	0.190	0.209	0.752
(37)	0.088	0.368	0.115	0.196	0.353	0.354
(38)	0.231	0.962	0.441	0.371	0.498	0.495
(39)	0.279	0.372	0.444	0.701	(0.731)	(0.686)
(40)	0	1.318	0.608	1.895	0.400	0.352
Total	4.402	6.042	5.910	9.838	10.870	10.148

Appendix 27. Individual Results for the KKF Experimental Friesian Animals.

COW NO.	H.b. (grms %)	P.C.V. (%)	R.B.C. (mill/ml)	W.B.C. (Thou/ml)	Lympho. (Thou/ml)	Neutro. (Thou/ml)	Eosino. (Thou/ml)
3	12.6	37.0	5.580	6.875	4.476	1.767	0.633
6	12.7	37.0	5.710	6.725	3.551	2.159	1.015
12	13.1	38.0	6.080	7.875	4.410	2.520	0.945
31	12.8	36.0	5.970	7.500	4.800	2.100	0.600
32	12.0	35.0	6.040	6.600	4.580	1.478	0.541
2	10.7	31.0	5.675	6.606	3.947	1.360	1.294
7	11.0	32.0	4.460	6.525	4.287	1.533	0.705
8	12.2	34.0	5.090	10.475	6.453	3.142	0.880
112	12.6	36.0	5.760	7.550	4.077	1.963	1.510
133	11.4	30.0	5.005	5.225	3.976	0.893	0.355
Mean	12.1	34.6	5.537	7.195	4.456	1.892	0.848