CHEMICAL AND CELLULAR CONSTITUENTS IN THE BLOOD OF GENETICALLY DIFFERENT LINES OF GROWING BEEF CATTLE

by

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A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

DOCTOR OF PHILOSOPHY

June 1958

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Date thesis is presented June 24, 1957

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ACKNOWLEDGEMENT

The writer wishes to express his sincere and grateful appreciation to Doctor Ralph Bogart, Professor of Animal Husbandry, and Doctor Hugo M. Krueger, Professor of Physiology, for their constructive suggestions and criticisms during the preparation of the thesis.

Appreciation is expressed to Doctor J. E. Oldfield, Associate Professor of Animal Husbandry, and Doctor G. A. Richardson, Professor of Dairying and Dairy Chemistry, for making available the laboratory facilities necessary for carrying out this investigation.

Appreciation is expressed to my fellow graduate students for their advice and interest, and especially to Mr. G. I. Alexander and Doctor John Kaufmes for their technical assistance in procuring and analyzing the blood samples.

Acknowledgements are also due to the staff members of the Department of Animal Husbandry for their efforts and friendship throughout the period of study.

Special recognition is due to the writer's wife, Janice, whose encouragement and help have made this study more enjoyable.

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CHAPTER I

INTRODUCTION

The more productive, and consequently the more efficient animal, given the proper environment, is such because of a hereditary make-up in which all the operating efficiency factors are developed harmoniously for the given high production level. Primary factors affecting production can be classified as genetic, environmental, physiological and economical.

The productive level is a very important aspect of the success of a beef cattle enterprise. Rate of gain and efficiency of gain of growing animals are important aspects of production in beef cattle. Controlled performance testing in selective breeding is an effective method of measuring gain per day and economy of gain. From estimates of heritability, Knapp and Nordskog (30, pp.62-70) concluded that the influence of heredity on gaining ability and efficiency of feed utilization by calves may be high enough to make selection, based on individual performance for these traits, effective without the use of progeny testing. But controlled performance testing is a time consuming procedure, so that

extensive adoption of this practice may meet with disfavor.

Information gathered from performance testing of beef cattle at the Oregon Agricultural Experiment Station and other stations substantiates the existence of wide individual differences in rate and efficiency of gain. Such wide differences should be reflected in the physiological complex of individual animals. The possibility of obtaining some simple biological measurement, or measurements, correlated with rate and efficiency of gain has attracted the interest of many investigators. The Oregon Agricultural Experiment Station has obtained a large amount of data involving blood and urine chemistry of beef cattle. MacDonald (38) presented data on blood and urine constituents derived from Hereford and Angus calves on feed test from 500 to 800 pounds body weight. Williams (69) conducted a study on the changes in certain blood constituents in Hereford calves at 500, 600, 700 and 800 pounds body weight. Nelms (44) studied the association of certain blood constituents and urinary 17-keto-steroids with rate and efficiency of gain data taken from Hereford calves on feed test from 500 to 800 pounds body weight.

The present study involves a continuation and expansion of the research on blood chemistry. Blood has been

taken from calves on feed test from 500 to 700 pounds body weight. Certain constituents of the protein-free filtrate of the blood have been measured; the blood plasma has been analyzed for the relative concentration of plasma and serum proteins and some studies have been made of the cellular components. The extent of the correlations between data on blood chemistry with rate and economy of gain have been evaluated. In addition correlations between various blood constituents have also been calculated.

CHAPTER II

REVIEW OF LITERATURE

A. Plasma and Serum Proteins of the Blood.

Perhaps no other tissue of the body is more essential, in more ways, to more vital activities than the blood. During the first year of growth in a calf, the physiological blood reactions are at their peak in activity, and the activity of these reactions at this particular time is equalled only during pregnancy of the dam.

In early studies with the microscope, the corpuscular elements were considered the prime factors. The blood plasma was considered only as a carrier for the corpuscular elements. Studies in recent years have shown the blood plasma to be more vital to the animal and as complex as the corpuscular elements. A good example of one important physical property of plasma proteins may be taken from Mack (40, p.4). The surface area of the protein molecules contained in the approximately 2700 ml. of plasma in the adult human body has been estimated to be approximately 35 acres, in contrast to only 0.8 acre for the surface area of erythrocytes.

Schoenheimer (58) and his associates, using the N^{15} technique, developed data to illustrate the dynamic state of the living system, emphasizing the rapid rate of

interaction between tissue constituents and components introduced in the diet. In this dynamic living system, complex molecules have been broken down to simple ones, to form a "metabolic pool" to which have been added components from the diet. There by a continuous series of rapid interactions, combinations are formed to meet the nutritive and other requirements of body tissues including repair and reconstruction of the molecules broken down. Allison (2, pp.664-700) said that the "metabolic pool" may be considered as due to the activities involving protein metabolism in many centers, which contribute and integrate into the dynamic state of the whole body.

Sprinson and Rittenburg (61, pp.715-726) measured the rate of synthesis of protein through the use of N^{15} labeled glycine, thereby estimating that approximately 1.3 gm. of protein per kg. of body weight have been synthesized daily in a 70 kg. adult human. From this information we may estimate that a 1000 pound cow would synthesize daily approximately 1.3 pounds of protein.

Synthesis of tissue protein is a relatively rapid process, which requires each amino acid to be oriented into its proper place at the proper time to develop each specific protein. If a single amino acid is missing the protein can not be synthesized. Rose (51, pp.109-136) did much of the early work on determining the essential

amino acids, i.e., those necessary in the diet. There is considerable variation between species in amino acid requirements. Many organisms can synthesize the majority of amino acids needed for the demands of anabolism.

Proteins are so complex and so labile that a detailed classification of them in a living system is indeed difficult. According to West and Todd (67) the total protein content of whole blood amounts to about 22 per cent. The hemoglobin of the red cells represents about two-thirds of the mass of blood proteins and the plasma proteins about one-third. The proteins of the stroma, leucocytes and platelets represent insignificant quantities of the total blood proteins.

Plasma proteins are referred to as albumins, globulins and fibrinogen. Howe (29, pp.93-109) developed a method of separating proteins of blood serum into albumin and globulin fractions by precipitation with sodium sulfate. By precipitating serum at sodium sulfate concentrations of 13.5, 17.4 and 21.5 per cent, Howe obtained what he designated as euglobulin, pseudoglobulin and total globulin values. The nitrogen in the supernatant fluid, after removing the precipitate obtained at 21.5 per cent sodium sulfate concentration, is assumed to represent albumin.

One of the best methods of describing the proteins of the plasma and their relative amounts depends upon their electrophoretic distribution. Tiselius (63, p.524) developed the electrophoretic method of protein analysis and applied it to a study of plasma proteins. Electrophoresis depends upon the tendency for charged particles in suspension or in solution to migrate in an electrical field in a direction and with a velocity determined by the size and shape of the molecules and by their electrical charge and by the properties of the solution. When ions in a mixture migrate at different rates, separations can be effected by electrophoresis. In an apparatus of the Tiselius type, the migration occurs within a glass U-tube connected through liquid columns to positive and negative electrodes. Migration rates and concentrations are evaluated by optical means.

As the different groups of proteins migrate at different speeds, but with most members of a given group moving at nearly the same speed, they form a series of peaks and valleys, the area under each peak indicates the quantity of the protein aggregate producing that segment of the boundary. Following the development of the moving boundary method of electrophoresis, methods for the separation of proteins by electrophoresis in filter-paper strips have been developed by Durrum (18, pp.274-290),

Kunkel et al. (34, pp.89-118), Kunkel (33, pp.141-169), Ghosh (21, p.257), Parker (48, pp.638-651), Sato (56, pp. 267-271) and others. Paper electrophoresis is a rapidly growing field for achieving the same information as provided by the moving boundary method. For the purpose of the present investigation on blood proteins the paper electrophoresis method has been employed. A more detailed account of the methods and principles involved in paper electrophoresis will be given in the methods and procedure section. Although this method provides less precise data for analytical purposes than the moving boundary method, it is of great value in studying the relative amounts of the various components present. An excellent review of the theory and methods of paper electrophoresis may be found in Block, Durrum and Zweig (6).

The electrophoretic patterns consist of a series of peaks in a definite sequence of sizes and shapes. In human plasma for example these peaks consist of albumin, alpha globulin, beta globulin, fibrinogen and gamma globulin fractions. It must be pointed out that although electrophoretic separation provides much more detailed information than does ordinary chemical fractionation, the areas under the separate peaks do not represent quantities of "pure" proteins, but indicate closely related proteins with similar mobilities. The peaks

obtained include those of simple proteins, lipoproteins, glycoproteins and traces of large numbers of proteins which function as immune bodies, enzymes and hormones.

Variations of plasma proteins under physiological conditions have been studied extensively, especially to show relations to various pathological states. Gutman (23) has summarized many of the findings of recent years.

An extensive review of literature on blood plasma and serum proteins yielded no previous information as to studies on the association of albumin and globulin fractions with rate of gain and economy of gain in beef cattle or other domestic animals. However, past investigations do provide normal values from which comparisons can be made with the present study. In an electrophoretic study of the blood plasma from twenty species of animals, including domestic animals and birds, Deutsch and Goodloe (16, pp.1-20) concluded that distinct species differences in the mobility, amount and number of protein components occur. There is much more constancy within, than between species.

Bradish et al. (7, pp.329-335) studied the sera of normal Devon steers (18 - 30 months old). The sera were analyzed using the moving boundary technique. The electrophoretic distribution was as follows: albumin 46.6, alpha globulin 14.0, beta globulin 8.9 and gamma

globulin 30.5 per cent; this latter component contained at least 3 minor components. They observed that in about 60 per cent of the steers the absolute concentration of serum proteins was 7.0 ± 0.5 gm. per 100 ml. and the concentration of the albumin was maintained relatively stable at approximately 3.2 gm. per 100 ml. while the concentration of the globulins underwent much greater variation. Earlier information based on the precipitation of protein fractions with salts is tabulated in Standard Values in Blood (Albritton, 1). Total plasma protein was 8.32 and fibrinogen 0.72 gm. per 100 ml. Total serum protein was 7.60 gms., serum albumin 3.63 gms., and serum globulin 3.97 gms. per 100 ml. This would give a serum albumin/globulin ratio of 0.91.

Armstrong et al. (4, pp.416-421) determined the protein distribution in normal pooled human plasma by electrophoresis. The serum albumin/globulin ratio for humans was 1.23. Electrophoretic distribution of serum proteins expressed as percentages of the total protein were given by Svensson (62, pp.805-826). The albumin, alpha globulin, beta globulin and gamma globulin were 41, 13, 8 and 38 per cent respectively. From this information the albumin/globulin ratio would calculate to be 0.69. From serum protein data given in West and Todd (67) it is noteworthy that the content of gamma globulins is higher

in the sera of the cow, guinea pig, horse, pig, rabbit and sheep than in man and that the amount of albumin is much lower in horse, cow and pig sera than in man.

Another study by Bradish et al. (8, pp.335-341) dealt with sera of cattle infected with the virus of foot and mouth disease. The sera from 21 cattle infected with the virus of foot and mouth disease were analyzed electrophoretically. The beta globulin rose from the normal level of about 10 per cent to about 14 per cent on the seventh day following inoculation but returned to the normal level within another week. The gamma globulin increased from the normal level of 30, to about 40 per cent during the third and fourth week and remained at this level with little change for several weeks. This increase was found to be the gamma globulin component of lowest mobility, which the authors stated was probably gamma-2 globulin.

In contrast to the electrophoretic changes in the sera of cattle infected with the virus of foot and mouth disease, Bradish et al. (9, pp.342-344) found that the sera of cattle with vesicular stomatitis showed no significant rise in concentration of beta globulin. An increase of from 3 to 10 per cent in the globulin fraction was observed between the third and sixth weeks after inoculation, but this was not identified with an increment

in the gamma-2 globulin component. Furthermore, the authors concluded that the electrophoretic changes are less pronounced and not as regular as those associated with the development of foot and mouth disease.

Using the paper electrophoresis method, Hartung (25, pp.300-301) analyzed the blood serum of normal and leukemic cattle. Hartung claimed that bovine serum could be separated into alpha 1, alpha 2, beta 1, beta 2 and gamma globulin and albumin proteins. Most investigators reviewed have not accomplished protein separation on beef serum to the degree obtained by Hartung. Hartung found that the total protein content rose from about 4 per cent at birth to 7 per cent at 11 years. Most of the total protein increase took place in the first 130 days of life, however the absolute concentration of albumin declined with age. Almost no gamma globulin was found in the serum at birth, but its absolute concentration was about 1 per cent at 60 days and 2.2 per cent at 11 years. The other serum components remained unaltered. The variations found in leukemia were not specific.

Wayman and Asdell (66, pp.296-303) reported an investigation on the physiology of bovine nymphomania. The blood plasma protein picture of nymphomaniac cows showed a highly significant variation from the control cows. The plasma protein fractionations were carried out by the

sodium sulfate method of Wolfson et al. (71, pp.723-726). Observations on 6 normal and 6 nymphomaniac cows showed a total protein of 7.61 gm. per 100 ml. for the normal and 9.23 gm. per 100 ml. for the nymphomaniac cows. The protein fractions for the normal cows were 3.05, 4.56, 0.65, 1.57 and 2.34 gm. per 100 ml. for albumin, total globulin, alpha globulin, beta globulin and gamma globulin respectively. The nymphomaniac cows had 2.81, 6.41, 0.73, 1.95 and 3.73 gm. per 100 ml. for albumin, total globulin, alpha globulin, beta globulin and gamma globulin respectively.

Cornelius et al. (14, pp.522-524), employing the same method of fractionation, studied the serum proteins, among other blood constituents, in bovine dwarfs. Data from 38 Hereford and Angus dwarfs ranging in age from 6 days to 14 months of age were given. Total protein concentration per 100 ml. was 6.03 ± 0.9 gm., albumin 2.7 ± 0.67 gm., alpha globulin 0.74 ± 0.26 gm., beta globulin 1.49 ± 0.55 gm. and gamma globulin 1.05 ± 0.26 gm., all per 100 ml. of plasma. The authors concluded that these serum protein values were all within normal limits for the bovine.

Some consideration should be given to the many studies of antibodies in the newborn. Mammals at birth do not appear to be capable of making antibodies (White

et al., 68). Instead, physiological mechanisms exist for creating a temporary passive immunity in the young which permits them to resist infection until the time when the mechanism of antibody synthesis has developed. In some mammals, including man, the specific antibodies present in the maternal plasma are demonstrable at birth in the blood of the young. For these species passive immunity is achieved by transfer of antibodies from maternal blood through the placenta to the blood of the fetus.

In the cow, horse, sheep, goat and some other animals, gamma globulins are absent in the serum of the newborn, and correspondingly, no antibodies can be detected in the blood. This indicates an apparent placental barrier to immunity. Smith and Holm (59, pp.349-357) demonstrated this absence of gamma globulin with the electrophoretic patterns of the serum of a newborn lamb. The serum was analyzed immediately after birth and at 3 days of age after suckling the dam. From the electrophoretic pattern it was apparent that a new component "col" had appeared in the serum after the lamb had suckled the dam. The authors demonstrated a similar phenomenon in the bovine.

Reference to plasma proteins related specifically to rate and efficiency of growth, was not located in the

literature. However, many of the papers do point out how vital the plasma proteins are to growth. The constancy of the pattern of plasma proteins observed, even in many of the abnormal conditions reported, points out the great capacity of the plasma proteins for maintaining a relatively constant internal environment in the living animal.

B. Non-Protein Nitrogenous Constituents of the Blood.

Extensive reviews on the non-protein nitrogenous constituents of the blood in growing animals have been presented by MacDonald (38), Williams (69) and Nelms (44). Consequently, a brief review of some of the more significant findings reported at this Station on the nitrogenous constituents of the blood seems sufficient. MacDonald et al. (39) presented data on blood and urine constituents derived from Hereford and Angus calves on feed test from 500 to 800 pounds body weight. Glucose, urea nitrogen and uric acid levels were lower in beef cattle than those reported for man; while creatinine levels were similar. Individual variability for glucose was less in beef cattle than in man. Variability for urea nitrogen, creatinine and uric acid was somewhat greater in beef cattle than in man. Angus calves generally showed higher concentrations of uric acid and amino acid nitrogen than Hereford calves. Angus calves showed higher

concentrations of blood creatinine than Hereford calves at 500 pounds, but at 800 pounds the reverse was noted. MacDonald et al. (39) reported lower levels of blood amino acid nitrogen in bull calves as compared to heifer calves and suggested that this may be associated with the faster gaining of the bull calves.

Williams (69) conducted a study on the changes in certain blood constituents which might be associated with growth and development of Hereford calves. Blood samples were analyzed at 500, 600, 700 and 800 pounds body weight. Blood uric acid, urea and amino acid nitrogen showed sex differences. The heifer calves showed higher levels of uric acid, urea and amino acid nitrogen. In addition, blood uric acid was related to line differences. Total feed intake was significantly related to blood uric acid, urea and amino acid nitrogen.

Nelms (44) related values for urea nitrogen, amino acid nitrogen, creatinine and uric acid in the blood with rate of gain and feed efficiency of Hereford males and females. In addition, the urinary 17-ketosteroids were determined and associated with rate and efficiency of gain in the same set of animals. The blood and urine constituents were determined at two body weights, 500 pounds and 800 pounds.

A significant line difference existed in blood urea nitrogen and blood creatinine at 500 pounds body weight. A significant line difference was noted in blood uric acid at 800 pounds body weight. A sex difference was also found in blood urea nitrogen and blood uric acid at 500 pounds. Blood creatinine and urea nitrogen were significantly related to age of the calf at 500 pounds body weight. A significant relationship between blood amino acid nitrogen and urinary 17-ketosteroids was observed. Price et al. (50) presented a correlation analysis of the information reported by MacDonald et al. (39) on the blood data and performance records of the 1952 calf crop. Amino acid nitrogen in the blood of the test calves at 800 pounds body weight was significantly and inversely related to the rate of gain per day. Blood amino acid nitrogen was significantly and positively correlated at both 500 and 800 pounds body weight with feed consumed per 100 pounds gain. Urea nitrogen levels determined in the blood at 500 pounds body weight increased as feed consumed per 100 pounds gain increased. Blood uric acid at 800 pounds showed a significant positive relationship to feed consumed per 100 pounds gain, but at 500 pounds the correlation was not significant. Blood creatine levels at 500 pounds body weight exhibited a significant negative relationship to feed consumed per 100 pounds

gain, but at 800 pounds the correlations were not significant. Glucose and creatinine were not correlated at either weight with the feed required per unit of gain. Urinary total nitrogen and urea nitrogen at 800 pounds body weight showed significant decreases as rate of gain per day increased, but were positively correlated with feed consumed per 100 pounds gain. Urinary creatine, creatinine, uric acid and total urine volume at 800 pounds body weight were not significantly correlated with either rate of gain per day or feed required per unit of gain. A more detailed discussion and review of literature may be found in the publications cited.

C. Hematology.

No attempt has been made to cover all areas of hematology, and only those particular references which the author considered pertinent to the present investigation are quoted. A most helpful source of information has been the manual, "Standard Values in Blood," edited by Albritton (1). Means, ranges and standard errors have been presented in this manual, as well as references to the literature from which the information was gathered.

In many cases, values in the literature on cellular constituents are for dairy cattle and not for beef cattle. However, some reviews of blood data do not state whether the source of information is from dairy cattle or beef

cattle. In the present review the type of animal is noted if it was given as such in the original work.

Maynard (41, pp.179-188) has discussed the value of certain physiological data in the diagnosis of nutritional status and concluded that the utilization of blood characteristics has added refinement to nutrition research, since the blood may be altered previous to the appearance of gross symptoms of dietary disturbance.

1. Red blood cells.

a. Hematocrit.

The hematocrit gives the proportion of packed red blood cells measured as a fraction of whole blood volume. Coffin (13) states that normally the red cell volume is in direct proportion to the red cell count and the hemoglobin level and that the hematocrit yields the same information as the red cell count or the hemoglobin determination, while it is more easily performed and less subject to error. However, in certain anemias this relationship changes and information can be obtained by correlating hematocrit, red cell count and hemoglobin.

Albritton (1) reports hematocrits ranging from 31 to 54 per cent with a mean value of 38.6 per cent in adult female dairy cattle. Holman (28, pp.379-384) reported a range of 28 to 42 per cent for packed cell volume in 50 dairy cows.

Under ambient temperatures, ranging from 50° to 100° F., the blood of Jersey and Holstein cows studied by Brody et al. (10) yielded hematocrit values from 30 to 38 per cent cell volume, with a few scattered values as low as 29 per cent and some as high as 42 per cent. There was an overall mean of 36.6 per cent for the control cows and 34.5 per cent for the experimental cows. Each cow in the experimental temperature chamber was subjected to temperatures of 50° to 100°F. while the control cows were subjected to temperatures of 50° to 60°F. Individual readings indicated that each cow has its own hematocrit range. The blood cell volume was not significantly affected by changes in ambient temperature.

Rusoff (55, pp.30-36) reported that hematocrit values for five Jersey bulls ranged from 29.5 to 49.5 per cent with a mean of 42.3 ± 0.9 per cent. The hematocrit values for five Guernsey bulls ranged from 34.0 to 53.5 per cent with a mean of 46.3 ± 1.2 per cent, while the values for five Holstein bulls ranged from 37.0 to 50.0 per cent with a mean of 39.5 ± 1.8 per cent.

Greatorex (22, pp.120-138) reported packed cell volume for 233 dairy calves ranging in age from birth to one year of age. Corpuscular volume ranged from 18.0 to 61.0 per cent while most of the calves had values of 30 to 50 per cent.

b. Total red blood cell count.

From compilations of information of several investigators, Coffin (13) reported a red blood cell count ranging from 5.4 to 9.0 million per cu.mm. for cattle. Dukes (17) gave an overall mean of 6.3 million per cu.mm. and a range of 4.90 to 9.79 per cu.mm. calculated from 144 samples on 6 dairy cows. Ferguson (19, pp.24-30) observed a mean of 6.33 million per cu.mm. with a range of 5.64 to 7.44 million per cu.mm. for dairy cattle.

Rusoff (53, pp.331-336) gave the following means for red blood counts on dairy cows: Jerseys 6.55, Guernseys 7.49 and Holsteins 7.84 million per cu.mm.

For red blood cell counts of dairy calves from birth to one year old, Greatorex (22, pp.120-138) reported the following values:

Age	Mean Counts
At birth	7.4 millions per cu.mm.
1 week	7.5 " " " "
8 - 12 weeks	8.1 " " " "
4 - 6 months	7.8 " " " "
12 months	7.5 " " " "

Long et al. (37) studied the composition of the blood taken from Hereford, Angus and Shorthorn beef cattle. All the breeds had a normal variation from 4.5 to 6.0 million counts per cu.mm. This seems low when compared with the data on dairy cattle. The difference may possibly be due to the indirect turbidity technique

used in determining the red cell count.

Cornelius (14, pp.522-524) found from data on 38 Hereford and Angus dwarf cattle ranging in age from 6 days to 14 months, a mean red cell count of 9.8 ± 1.6 million per cu.mm.

c. Hemoglobin.

Investigations by Kronacher (31, pp.183-227) (32, pp.177-244) and Van Geller (64, pp.699-703) showed that the hemoglobin value of dairy cows increased during the summer on pasture over the values determined on the cows in dry lot during the winter. McCay (42, pp.373-378) could find no significant difference between the blood hemoglobin values during barn and pasture feeding.

There is considerable variation in the literature on hemoglobin values and the levels of other blood constituents. Anderson et al.(3, pp.336-348) found no correlations of hemoglobin with milk production, fat production, period of gestation, or period of lactation. They observed higher hemoglobin values in cows than in bulls. McCay (42, pp.373-378) reported that dairy cows averaged 10.6 gm. per 100 ml. and dairy bulls about 12.8 gm. of hemoglobin per 100 ml. of blood.

Dukes (17) reports 12.2 gm. hemoglobin per 100 ml. of blood as the normal value of the dairy cows, whereas

McCay (42, pp.373-378) regards 10.9 gm. as normal for the dairy cow and 12.8 gm. per 100 ml. normal for the dairy bull. On the other hand Anderson (3, pp.336-348) found dairy cows had higher hemoglobin values than dairy bulls. Much of this conflicting evidence is possibly due to many and varied methods of determining hemoglobin concentration in the blood. It would be very desirable if standard methods could be adopted for the determination of blood constituents which are routinely studied.

Rusoff (53, pp.331-336) found significant differences in hemoglobin values between herds of dairy cattle at different locations. No difference was found upon comparing blood hemoglobin observations between cows on a high plane with those on a low plane of nutrition. Blood hemoglobin values ranged from 11.2 to 13.4 gm. per 100 ml. for both groups of cows on the plane of nutrition study.

Greatorex (22, pp.120-138) studying dairy calves from birth to weaning, reported the hemoglobin values ranged between 4.6 and 16.1 gm. per 100 ml. of blood; however, the majority of calves gave readings of 9.0 to 14.5 gm. per 100 ml. Rusoff (54, pp.1145-1150) found differences between Red Sindhi-Jersey cross cows and Jersey dams in blood hemoglobin content. This difference was attributed to breed differences. Rusoff (55, pp.30-

36) found no significant differences between breeds for blood hemoglobin content of Jersey, Guernsey and Holstein cows. A significant difference in blood hemoglobin values between Holstein and Jersey cows was found by Byers et al. (12, pp.661-667). The Jerseys were found to have an average blood hemoglobin value of 11.3 gm. and the Holsteins an average value of 10.6 gm. per 100 ml. of blood. Pasture feeding did not change the blood hemoglobin values significantly from values obtained from barn feeding. In addition average blood hemoglobin of males did not differ significantly from that of females.

Long et al. (37) found no breed difference between Hereford, Angus and Shorthorn beef cows for blood hemoglobin content. Cornelius (14, pp.522-524) determined blood hemoglobin values for dwarf beef cattle and concluded that a mean value of 11.7 ± 1.4 gm. of hemoglobin per 100 ml. of blood was within the normal range for the bovine species.

MacDonald et al. (39) reported an average value of 12.0 gm. of hemoglobin per 100 ml. of blood for Hereford and Angus beef calves on performance test at 500 and 800 pounds body weight. Blood hemoglobin on the average was higher in females than in males, and this was especially true in the Angus calves. Average blood hemoglobin was higher in the Angus than in the Herefords for both males

and females.

Nelms et al. (45) recorded blood hemoglobin values on Hereford calves on performance test. The females had a mean of 13.4 gm. per 100 ml. and the males had a mean of 12.7 gm. of hemoglobin per 100 ml. of blood.

Price et al. (50) showed that hemoglobin at 800 pounds body weight was positively related to feed consumed per 100 pounds gain during the feed test, whereas at 500 pounds the correlation was not significant.

d. Ratios between hematocrit, red cell count and hemoglobin.

Wintrobe (70) developed ratios to describe mean corpuscular hemoglobin content and mean corpuscular volume. In addition he described mean corpuscular hemoglobin concentration as the percentage of hemoglobin of the corpuscular volume. The mean corpuscular hemoglobin portrays the ratio between the amount of hemoglobin and the number of red cells in the blood, expressed in the number of grams x 10^{-12}. The mean corpuscular volume value shows the ratio between the volume of packed cells and the number of red cells in the hematocrit tube. It is a measure of the actual volume of the individual erythrocyte. The mean corpuscular volume is expressed in cubic microns. Mean corpuscular hemoglobin

concentration expresses, in percentage, the relationship between the hemoglobin in grams and the mean corpuscular volume in cubic microns.

Normal ranges reported on cattle by Coffin (13) are 14.4 to 18.6 micromicrograms for mean corpuscular hemoglobin; 49.5 to 60.7 cubic microns for mean corpuscular volume and 32 to 34 per cent for mean corpuscular hemoglobin.

Albritton (1) gives a range of 14.2 to 18.5 micromicrograms with a mean of 15.7 micromicrograms for corpuscular hemoglobin content of the blood of the adult cow. The mean corpuscular volume ranged from 47 to 54 cubic microns with a mean of 50.0 cubic microns.

Greatorex (22, pp.120-138) calculated the mean corpuscular volume on 233 dairy calves from birth to one year of age. The extreme values were 28 to 112 cubic microns whereas the mode was from 40 to 60 cubic microns and individual values were evenly distributed throughout the first 12 months of life.

The mean corpuscular hemoglobin concentration of the majority of calves ranged from 21 to 40 per cent.

2. White blood cells.

a. Total white cell count.

Greatorex (22, pp.120-138) found the number

of leucocytes per cu.mm. of blood, in dairy calves from birth to a year of age, ranged between 4,500 and 15,000, with the majority ranging from 6,500 to 11,500 per cu.mm.

In dairy cows Hayden and Fish (27, pp.199-203) reported an average total leucocyte count of 9034 per cu.mm. of blood; Ferguson (19, pp.24-30) 8912 per cu.mm.; Rusoff (53, pp.331-336) a range of 8411 to 10,268 per cu.mm. and Brody (10) 8,570 per cu.mm. of blood. Rusoff (55, pp.30-36) reported 8580 per cu.mm. of blood in dairy bulls.

Recent investigations related to bovine dwarfism have attempted to use leucocyte count as one of the criteria for determining breeding animals which carry the dwarf gene. Cornelius (14, pp.522-524) found that all hematological values appeared normal with the exception of the differential leucocyte count. The total white cell count average of 8,800 per cu.mm. was within the normal range for the bovine. Several state experiment stations have made use of the total white cell count while conducting investigations on the detection of the dwarf carrier animal. According to Schneider (57, pp.56-57) a relatively simple and inexpensive test for identifying dwarf-carrier animals is being developed by Dr. John Lasley of the University of Missouri. This test uses insulin injections as a means of placing animals to be tested under a so-called "stress" condition. Such injections bring a

marked and rapid increase in the number of white blood cells in the blood stream of the dwarf-free or "clean" animal. Reaction in the dwarf-carrier animals is noticeably slower and weaker. The white blood cell count of a dwarf animal increases very little and at a very slow rate.

b. Differential leucocyte count.

Investigators working with the insulin tolerance technique of detecting dwarfism in beef cattle state that the kind and number of white blood cells are the key factors to the test. This points out the necessity for developing normal blood values in beef cattle research to provide a sound basis for future investigations.

Volumes of data have been recorded on the differential white cell count in cattle, chiefly on dairy cattle. A recent, comprehensive review has been compiled by Moberg (43). Coffin (13) gives normal ranges and means for differential white cell counts of cattle. Neutrophils range from 15 to 55, with a mean of 30 per cent; eosinophils range from 1 to 15, with a mean of 8 per cent; basophils range from 0 to 1, with a mean of 0.5 per cent; lymphocytes range from 40 to 70, with a mean of 52 per cent; and monocytes range from 3 to 15, with a mean of 9 per cent.

D. Performance Test.

Many different approaches to the problem of selecting the most desirable animals for beef production have been investigated. The past decade has seen many workers attempt to evaluate the productivity of beef cattle by means of the performance test.

Excellent reviews are available on the post-weaning performance of beef calves (Roubicek 52, MacDonald 38).

CHAPTER III

METHODS AND PROCEDURE

Data presented in this investigation were taken from 45 beef calves maintained at the Oregon Agricultural Experiment Station at Corvallis, Oregon.

There are two breeds, Hereford and Angus, represented on the performance test investigations. The Hereford groups are made up of three closed lines, i.e., only the breeding animals used in a line are those produced within that particular line.

The Lionheart line of cattle has been closed to any outside breeding since 1950. The Prince and David lines originated from the same stock. No outside bulls have been used for breeding in the Prince line since 1948, and no outside bulls have been used for breeding in the David line since 1950. Before 1950 some of the cows migrated back and forth between the Prince and David lines, but since 1950 these two lines have been maintained separately.

A. Management.

The calves represented in this study were born in the spring of 1956 and were weaned at about 425 pounds body weight. Those calves not reaching 425 pounds before November 14, 1956 were weaned regardless of their weight. After the calves were taken from their dams, they were

placed under experimental conditions.

The calves were grouped by sexes into pens of 6 animals. From the first feed period until the end of the test period the calves were tied by neck chains at individual feeding stalls twice a day. The feeding periods of approximately 3 to 5 hours twice daily were maintained as uniformly as possible. Calves had access to automatic water fountains at all times. The period between 500 and 800 pounds body weight was considered as the test period.

The management procedures used and recommended by Dahmen and Bogart (15) were followed and the calves were fed a completely pelleted ration, composed of 2 parts chopped alfalfa and one part concentrate. The ration is described in more detail by Nelms et al. (45).

B. Blood Collection.

Three separate blood samples were collected at 500 pounds body weight. Either 15 or 16 gauge bleeding needles were used. One sample of about 10 ml. was collected into an oxalated tube to prevent coagulation. The oxalate technique was as recommended by Washko (65, p. 359), which called for drying the oxalate in an oven to prevent disturbing the actual volume composition of the blood as much as possible. The other sample of about 6 ml. was collected in a 50 ml. graduated centrifuge tube

containing no oxalate to obtain blood serum after coagulation and centrifugation. Another 6 ml. oxalated sample was obtained in a graduated tube in order to determine the red blood cell volume.

The blood samples were obtained from the test calves about 9:00 a.m. to 10:00 a.m. and the blood analysis was initiated immediately.

C. Chemical Analyses.

1. Plasma protein fractionation by paper electrophoresis.

The separation of plasma and serum proteins into their component parts was carried out with a Spinco Model R paper electrophoresis apparatus exactly as instructed in the operating manual (60).

In brief the sample to be separated was applied as a narrow strip across a strip of filter paper moistened with electrolyte. The ends of the strip were connected through reservoirs of electrolyte to positive and negative electrodes. When the various components had migrated and formed separate bands along the paper strip, the strip was oven-dried to fix the pattern. The bands of serum proteins coagulated by the heat were then made visible by staining. Concentrations of the various components were determined on the basis of light

absorption of the stain. A commercial integrating scanner (60) was used to determine the relative concentration of the different protein components on the stained paper strips.

In this type of scanner, the area under the density curves is shown by a corresponding series of pips, every tenth pip being longer than the rest. Perpendiculars are dropped from the density curve, and the number of corresponding pips is directly proportional to the area under this curve. This scanner is provided with an optical density cam. These special cams can be calibrated to plot percent concentration directly for any standard dying procedure. Block states (6, p.402), "It is likely that scanners of this type will make the question of validity of Beer's law applied to direct paper scanning, largely of academic interest, since correction for the optical difficulties involved in measuring dye on paper can be incorporated empirically into the cam."

2. Non-protein nitrogen.

The non-protein nitrogen of the blood includes the nitrogen from all of the non-protein nitrogenous constituents of blood which are found in a protein-free filtrate, including such materials as urea, uric acid, amino acids, creatine, creatinine, glutathione and many others in small amounts. Haden's modification (24, pp.

469-471) of the Folin-Wu preparation of protein-free blood filtrate (20, pp.81-110), was used. For photometric determinations, percent transmission was determined with a Coleman Spectrophotometer using 1 cm. calibrated cuvettes.

The determinations of hemoglobin, urea, uric acid and amino acids are carried out routinely in the Genetics laboratory of the department of Dairy and Animal Husbandry at Oregon State College and the methods have been described previously by MacDonald (38) and Williams (69).

D. Cellular Components.

1. Hematocrit.

Six milliliters of blood were placed into a 15 ml. graduated centrifuge tube, containing potassium oxalate. The tubes were placed in an International No. 2 centrifuge and spun at 3000 revolutions per minute for 45 minutes. After centrifugation the volume of packed cells and total volume was determined to the nearest .1 of a milliliter. A percentage value for the hematocrit was calculated as (100 x ml. of red cells)/(ml. of total volume.)

2. Total red blood cell count.

Oxalated venous blood was used. Standard red blood cell counting pipettes and Spencer counting chambers

with improved Neubauer double rulings were employed. The blood was diluted in the pipette 1 to 200. Hayem's solution, composed of sodium chloride, sodium sulfate and mercuric chloride in water was used as a diluting fluid (36). After dilution the blood cells were dispersed in the Hayem's solution by placing the pipettes containing the sample in a mechanical shaker for 3 minutes. The technique for mounting the blood sample and counting is described in detail by Osgood (47). The samples were counted in duplicate and the average taken. According to Plum (49, pp.342-364) the error in counting depends more on the total number of cells counted than on the area. From the results of Plum's investigation, this laboratory concluded that counting 600 or more cells was sufficient. The accuracy of determinations made on oxalated blood deteriorates after certain time intervals, and the limits given by Osgood (46) were noted. The red cell count was performed within 24 hours after collection.

3. Total white blood cell count.

Essentially the same technique used in the red cell count was applied to white cell counting. Oxalated blood was used and diluted 1 to 20 with standard white blood cell diluting pipettes. Turk's solution was used for diluting the blood cells as described by Zoethout (72). A Levy leucocyte counter with Fuchs - Rosenthal

double ruling was employed. Again, as for red cell counting, the accuracy depends on the total number of cells counted. With Turk's solution the dark dots representing the stained nuclei of the white cells are counted. The cytoplasm of the white cells becomes transparent and the red cells are destroyed by the acid in the diluting fluid. The counts were performed in duplicate and the average value taken as the individual observation.

4. Differential white cell count.

The differential white cell count was made by spreading blood in a thin film on a clean slide, fixing it and staining with a differential stain.

The stain used was Wright's modification of the Romanowsky stain. The slide was then examined under an oil immersion lens and the white cells classified as seen until 100 were counted. Osgood (46) recommends Wright's stain: 140 mg. in 100 ml. of C.P. anhydrous methyl alcohol. The majority of the cells were classified as lymphocytes, eosinophils, neutrophils, basophils, monocytes and stab cells.

E. Statistical Analyses.

The data were analyzed by standard statistical techniques as outlined by J. C. R. Li (35). Means, standard errors, ranges and correlations have been reported. The

data have been broken down by sex, breed and line.

CHAPTER IV

EXPERIMENTAL FINDINGS

The data to be presented were obtained from 45 Hereford and Angus bulls and heifers at about 500 pounds body weight. The feedlot performance data were recorded from 500 to 700 pounds body weight.

The information derived from this study has been classified and presented as follows:

Means, ranges and standard errors of the means for the various blood constituents and feed lot performance data have been presented in tabular form (Tables 1, 2, 3, 4, 5, 6, 7, 8). The data were classified so that a comparison between sexes within breeds, comparison of sexes between lines, sexes within lines and an overall comparison between sexes could be made.

Gross correlations between the various blood constituents and feed lot performance data of the test calves have been calculated. Gross correlations between some of the blood constituents have been added.

Differences between means for group comparisons have been tested statistically by Student's "t" test. Probabilities of 0.05 or less have been taken to indicate statistically significant differences. No comparative differences have been discussed unless analysis yielded a probability of 0.05 or less. Thirty-four out of the 46

line, breed and sex differences reported were significant at the .01 level, the remaining 12 group differences were significant at the .05 level. This indicated that for the most part, where differences did occur between groups, the differences were highly significant statistically. In the discussion, comments have been made on the biological significance of some of the differences.

A. Sex Differences.

1. All male versus all female calves.

Male calves were superior to female calves for rate of gain in the feed lot from 500 to 700 pounds body weight. Male calves gained 2.71 pounds per day and female calves gained 2.11 pounds per day (Table 1). Male calves consumed, on the average, 216 pounds less feed to gain 100 pounds in body weight. The female calves consumed 897 pounds of feed per 100 pounds gain and the male calves consumed 681 pounds of feed per 100 pounds gain in body weight as shown in Table 1.

Suckling gains (Table 2) were not significantly different when all males were compared with all females. However, gain from birth to 700 pounds body weight (Table 2) was greater in the males than the females. From birth to 700 pounds body weight, the male calves gained 0.20 pounds per day faster than the female calves.

Few dissimilarities were found, when all male calves and all female calves were compared with respect to blood plasma constituents and blood cellular constituents. Blood urea nitrogen was lower in all males when compared with all females, as illustrated in Table 3.

Hemoglobin, shown in Table 4, was lower in the male calves than in the female calves. There was an average of 11.7 gm. and 12.5 gm. per 100 ml. of blood for males and females, respectively.

Males and females were similar with respect to uric acid, amino acid nitrogen, hematocrit, red cells, white blood cells and blood proteins, as shown in Tables 3, 4, 5 and 8, respectively. Even the ranges for the different constituents appear uniform.

2. Hereford males versus Hereford females.

Hereford males were superior to Hereford females in the feed lot as illustrated by Table 1. Hereford males gained an average of 2.79 and Hereford females 2.26 pounds per day from 500 to 700 pounds in body weight. Hereford males were more efficient, consuming an average of 648 pounds, while Hereford females consumed an average of 803 pounds of feed to gain 100 pounds in body weight. There was no advantage for either sex when suckling gains were examined. Hereford males did show a significant advantage when gains from birth to 700 pounds were examined.

Hereford males had an average of 2.04 pounds as compared to 1.79 pounds per day for Hereford females. The average values for suckling gains and gains from birth to 700 pounds body weight may be observed in Table 1.

Hereford males exhibited significantly lower average levels of urea nitrogen when compared with Hereford females. Hereford males had 14.61 mg. while Hereford females had 17.25 mg. per 100 ml. of blood as shown in Table 3.

Hereford males had a lower average hemoglobin value of 11.4 gm., as compared to 12.7 gm. per 100 ml. of blood for Hereford females as shown in Table 4. Average values in Table 5 show that Hereford males have 7.14 billion red cells per cu.mm. of blood, while Hereford females had 8.18 million red cells per cu.mm. of blood.

No significant differences were found between Hereford males and Hereford females for the other blood constituents studied.

3. Angus males versus Angus females.

Angus male calves had an advantage in feed lot performance over Angus female calves. Table 1 illustrates that Angus males gained an average of 2.53 pounds per day as compared to 2.02 pounds per day for Angus females on feed test. Angus males were more efficient. The average

feed consumption per 100 pounds of gain was 751 pounds for Angus males and 957 pounds for Angus females. No significant differences were found between Angus males and females with respect to suckling gains and gains from birth to 700 pounds body weight (Table 2).

Angus males and females were similar in regard to blood plasma and blood cellular constituents with one exception. Blood urea nitrogen was lower in the males than in the females as shown in Table 3. The Angus males averaged 14.71 mg. while the Angus females averaged 17.05 mg. per 100 ml. of blood.

4. Lionheart males versus Lionheart females.

No practical comparisons in this case were possible. Only one female was represented in the Lionheart line; consequently no standard error of the mean was calculated and no range was given in the tables.

5. Prince males versus Prince females.

Prince males and females were similar in feed lot and suckling performance with the exception of feed efficiency. The Prince males consumed less feed per unit of gain than any other group in the study.

The Prince females consumed less feed per unit of gain than any other group of female calves in the performance test. Prince males had an average feed

consumption of 631 pounds per 100 pounds gain while Prince females had an average feed consumption of 784 pounds of feed per 100 pounds gain in body weight as shown in Table 1.

Comparisons between Prince males and females for the various blood constituents showed that Prince males were lower in hemoglobin, hematocrit, eosinophil and neutrophil averages than Prince females. The average lymphocyte percentage was higher in Prince males than Prince females.

The average hemoglobin value was 11.1 gm. in the Prince males as compared to 12.6 gm. per 100 ml. of blood for the Prince females (Table 4). The average hematocrit, (Table 4), for the Prince males was 37.0 per cent and 41.7 per cent for Prince females. Table 7 shows that Prince males have average values of 77.5, 2.3 and 12.8 per cent for lymphocytes, eosinophils and neutrophils in the order listed. Prince females have average values of 67.0, 6.8 and 22.2 for lymphocytes, eosinophils and neutrophils respectively.

No other dissimilarities were found between Prince males and females as regards the remaining items studied.

6. David males versus David females.

David males were superior to David females for rate of gain on feed test, feed efficiency and gains from birth to 700 pounds body weight. There was no difference

between males and females for suckling gains. Values in Tables 1 and 2 show that David males averaged 2.93 pounds for rate of gain on feed test and David females averaged 2.30 pounds per day. David males consumed an average of 648 pounds and David females an average of 794 pounds of feed to gain 100 pounds in body weight. David males gained 2.05 pounds per day, while David females gained 1.64 pounds per day from birth to 700 pounds.

Few differences were found when the blood values for David males and females were compared. However, David males did have a lower red cell count and a higher mean corpuscular volume than David females as shown in Tables 5 and 6. The red cell count was 7.22 for David males and 8.65 million per cu.mm. of blood in the David females. The mean corpuscular volume was 53.20 cubic microns in the David males and 46.65 cubic microns in the David females.

One of the few instances of plasma protein fraction differences was exhibited in the David line. David males averaged 37.5 per cent and David females averaged 29.3 per cent gamma globulin as shown in Table 8.

B. Comparisons Between Breeds.

1. Hereford males versus Angus males.

Examination of averages for suckling gains in

Table 2 and feed lot performance averages in Table 1 shows that Hereford males are superior to Angus males in all performance traits measured. However, the only statistically significant advantage for Hereford males as compared to Angus males was in feed efficiency. Hereford males consumed an average of 648 pounds while Angus males consumed an average of 751 pounds of feed to gain 100 pounds in body weight.

Hereford males had lower hematocrit, total red cell count and hemoglobin averages than Angus as shown in Tables 4 and 5. Hereford males show an average hematocrit of 37.4 per cent while Angus males have an average hematocrit of 41.6 per cent. The average red cell count was 7.14 and 8.07 million per cu.mm. of blood for male Hereford and male Angus calves respectively. Angus males had an average of 12.5 gm. as compared to Hereford males with an average of 11.4 gm. of hemoglobin per 100 ml. of blood.

Hereford and Angus males differed significantly in their average differential leucocyte counts expressed as a percentage of the total leucocyte count. Hereford males were higher in lymphocytes with 76.2 per cent as compared to Angus males with 61.0 per cent as shown in Table 7. Angus males had an average of 28.6 per cent neutrophils and Hereford males 15.6 per cent.

Hereford males had a lower plasma albumin average and a lower albumin/globulin ratio than Angus males as shown in Table 8. Hereford males averaged 34.3 per cent and Angus males 38.1 per cent plasma albumin. The albumin/globulin ratio was 0.53 for Hereford males and 0.62 for Angus males.

No differences between Hereford and Angus males were found for the remaining blood constituents.

2. Hereford females versus Angus females.

Hereford females were superior to Angus females in feed lot performance. There was no statistically significant advantage for the Hereford breed with respect to suckling gains and gains from birth to 700 pounds body weight. Hereford females, as shown in Table 1, gained 2.26 pounds as compared to Angus females with 2.02 pounds per day. Hereford females consumed 803 pounds feed per 100 pounds in gain while Angus females consumed 957 pounds of feed per 100 pounds gain in body weight (Table 1).

There were few dissimilarities between Hereford and Angus females for the various blood constituents. The only dissimilarity appeared in the differential leucocyte count and this was similar to the difference that was found between Angus males and Hereford males. Hereford

females had 73.6 per cent lymphocytes while Angus females had 63.2 per cent lymphocytes as illustrated in Table 7. The average values in Table 7 show that Hereford females had 16.4 per cent as compared to 27.9 per cent neutrophils for Angus females.

Hereford females and Angus females were similar with respect to the other blood constituents and showed no significant differences for suckling gains or gains from birth to 700 pounds in body weight as shown in Table 2.

C. Comparisons Between Lines.

1. Comparisons between Lionheart, Prince and David males.

Few dissimilarities were found between male animals within the Hereford breed. In only one case was the difference significant at the .01 level.

Lionheart males as shown in Table 5 had a higher white cell count than Prince males. No other significant differences were found in the cellular constituents of the blood. Lionheart males had a higher beta globulin fraction in the blood plasma proteins than the Prince males. The average value was 14.0 per cent for the Lionheart males as compared to 11.3 per cent beta globulin for Prince males.

The only significant difference between Lionheart

and David males was found in blood urea nitrogen as shown in Table 3. The Lionheart males averaged 13.25 mg. while the David males had an average value of 16.52 mg. per 100 ml. of blood.

Prince and David males were similar in all respects with the exception of the white cell count and the beta globulin fraction. Prince males had a much lower white cell average, 8430 per cu.mm. as compared to 10,900 white cells per cu.mm. of blood for David calves.

Prince males showed a lower beta globulin fraction than David males. The average beta globulin was 11.3 per cent in the Prince calves and 14.2 per cent in the David calves.

No additional dissimilarities were found when Lionheart, Prince and David male calves were compared with regard to feed lot performance, blood plasma and cellular constituents.

2. Comparisons between Lionheart, Prince and David females.

David females had a very low average suckling gain. In fact, the average suckling gain of 1.48 pounds per day for the David females was the lowest average reported (Table 2). The Prince females had an average suckling gain of 1.77 pounds per day.

On the performance test, no significant differences were found between David females and Prince females as shown by Table 1.

Prince females had a significantly higher mean corpuscular volume than David females. The average corpuscular volume was 55.8 cubic microns for the Prince females as compared to 46.7 cubic microns for the David females (Table 6).

Prince and David females differed in their differential leucocyte counts as shown by Table 7. Prince females averaged 6.8 per cent for eosinophils and 22.2 per cent for neutrophils while David females averaged 2.3 and 13.7 per cent for eosinophils and neutrophils in the order listed.

No significant differences were found for the remaining blood constituents when Prince females and David females were compared.

Only one female was represented in the Lionheart line, thus no statistical comparison was possible with the other lines.

D. Gross Correlations on Feed Lot Performance and Blood Constituent Data.

Gross correlation coefficients were calculated on some of the performance test information and blood data

in an attempt to more clearly understand the biological significance of the information gathered. Correlation coefficients were calculated between rate of gain and all of the other items represented in the investigation. For example, feed consumed per pound of gain, suckling gains, the protein and non-protein nitrogenous constituents of the blood, the cellular constituents and the performance test data and blood values were correlated with rate of gain. The same procedure was followed for all of the items in the study. Some of the more statistically significant correlations have been found as follows:

1. Correlations between performance test measurements.

Rate of gain per day from 500 to 700 pounds body weight was positively related to rate of gain per day from birth to 700 pounds body weight and inversely related to feed intake per unit of gain. Also, gain from birth to 700 pounds was negatively correlated with pounds of feed consumed per unit of gain and positively correlated with suckling gains.

2. Correlations between performance test measurements and some of the blood constituents.

Rate of gain per day on feed test was significantly and inversely related to blood hemoglobin, urea

and albumin. Figure 1 illustrates graphically the correlation between rate of gain per day and blood hemoglobin.

Gain per day from birth to 700 pounds body weight showed a significant inverse relationship to blood hemoglobin and hematocrit.

Feed consumption per 100 pounds gain in weight was significantly and positively correlated with blood hemoglobin, hematocrit, urea and uric acid. The relationship between feed consumption and blood hemoglobin is illustrated in Figure 2.

Suckling gains were inversely related to mean corpuscular hemoglobin concentrations. None of the remaining blood constituents, such as amino acid nitrogen, the plasma globulins or white cells were significantly related to performance test data.

3. Correlations between some of the blood constituents.

Highly significant relationships were found between blood hemoglobin, hematocrit and total red blood cell count. In addition, red cell count was highly related to plasma gamma globulin.

Blood urea nitrogen was significantly related to both blood uric acid and amino acid nitrogen. An illustration of the relationships between urea nitrogen and uric acid and amino acid nitrogen has been given in

Figures 3 and 4.

Correlations were not calculated between the plasma protein fractions, i.e., among themselves. No further statistically significant relationships were found among the various blood constituents analyzed.

The findings presented may be summarized as follows:

A. Sex Differences:

1. All males, on the average, have:
   higher rate of gain per day on feed tests
   lower feed consumption per unit gain
   higher rate of gain per day from birth to 700 pounds body weight
   lower hemoglobin
   lower urea nitrogen
   than all females.

2. Hereford males, on the average, have:
   higher rate of gain per day on feed test
   lower feed consumption per unit gain
   higher suckling gain
   lower urea nitrogen
   lower hemoglobin
   lower red cell count
   than Hereford females.

3. Angus males, on the average, have:
   higher rate of gain per day on feed test
   lower feed consumption per unit of gain
   lower urea nitrogen
   than Angus females.

4. Prince males, on the average, have:
   lower feed consumption per unit of gain
   lower hemoglobin
   lower hematocrit
   lower lymphocyte count
   lower eosinophil count
   lower neutrophil count
   than Prince females.

5. David males have:
   higher rate of gain per day on feed test
   lower feed consumption per unit gain
   higher rate of gain per day from birth to 700 pounds body weight
   lower red cell count
   higher mean corpuscular volume
   higher gamma globulin fraction
   than David females.

B. Breed Differences:

1. Hereford males, on the average, have:
   lower feed consumption per unit gain
   lower hemoglobin
   lower hematocrit
   lower red cell count
   higher lymphocyte count
   lower neutrophil count
   lower albumin
   lower albumin/globulin ratio
   than Angus males.

2. Hereford females, on the average, have:
   higher rate of gain per day on feed test
   lower feed consumption per unit gain
   higher lymphocyte count
   lower neutrophil count
   than Angus females.

C. Line Differences Among Males:
white cell count L > P; D > P
Beta-globulin L > P D > P
Blood urea L > D

D. Line Differences Among Females:
gain per day P > D
mean corpuscular volume P > D
neutrophils P > D
eosinophils P > D

E. Gross Correlations on Feed Lot Performance and Blood Constituent Data:

1. The correlation coefficient between rate of gain per day from 500 to 700 pounds body weight and:
   a. feed intake per unit of gain was -0.84.
   b. gain from birth to 700 pounds was 0.44.
   c. blood hemoglobin, -0.40.

d. blood urea nitrogen, -0.33.
e. blood plasma albumin, -0.30.

2. The correlation coefficient between daily gain from birth to 700 pounds body weight and:
   a. feed intake per unit of gain was -0.45.
   b. suckling gains, 0.67.
   c. blood hemoglobin, -0.31.
   d. blood hematocrit, -0.38.

3. The correlation coefficient between feed intake per unit of gain and:
   a. blood hemoglobin, 0.38.
   b. blood hematocrit, 0.34.
   c. blood urea nitrogen, 0.33.
   d. blood uric acid, 0.32.

4. Correlation coefficients between some of the blood constituents:
   a. blood hemoglobin to blood hematocrit, 0.70.
   b. blood hemoglobin to total red blood cell count, 0.66.
   c. blood urea nitrogen to amino acid nitrogen, 0.59.
   d. blood urea nitrogen to uric acid, 0.51.
   e. total red blood cell count to plasma gamma globulin, -0.42.

Table 1. Average Rate of Gain and Pounds of Feed Consumed per 100 Pounds Gain of the Test Calves from 500 Pounds Body Weight to 700 Pounds Body Weight.

Group	Number of Calves	Rate of Gain on Test		Feed Consumption	
		Average (lbs. per day)	Range	Average (lbs. Feed per 100 lbs. Gain)	Range
Lionheart males	3	2.75	2.60-2.94	681	628-733
Lionheart females	1	2.07	---	918	---
Prince males	6	2.67	2.13-3.22	631	551-677
Prince females	4	2.26	2.04-2.61	784	713-830
David males	6	2.93	2.56-3.08	648	580-717
David females	4	2.30	2.14-2.45	794	689-874
Angus males	7	2.53	1.96-3.10	751	605-897
Angus females	14	2.02	1.68-2.60	957	719-1131
Hereford males	15	2.79	2.13-3.22	648	551-733
Hereford females	9	2.26	2.04-2.61	803	689-918
All males	22	2.71	1.96-3.22	681	551-897
All females	23	2.11	1.68-2.61	897	689-1131
All animals	45	2.40	1.68-3.22	791	551-1131
Standard error of the Mean for All Animals		± 0.06		± 22.5	

Table 2. Average Suckling Gain and Average Rate of Gain of the Test Calves from Birth to 700 Pounds Body Weight.

Group	Number of Calves	Suckling Gain Average (lbs. per day from birth to weaning)	Suckling Gain Range	Gain from Birth to 700 Pounds Average (lbs. per day)	Gain from Birth to 700 Pounds Range
Lionheart males	3	1.80	1.58-1.95	2.10	1.90-2.20
Lionheart females	1	1.87	---	1.95	---
Prince males	6	1.80	1.42-2.19	2.01	1.74-2.16
Prince females	4	1.77	1.52-1.91	1.89	1.78-1.95
David males	6	1.73	1.14-2.03	2.05	1.90-2.19
David females	4	1.48	1.38-1.61	1.64	1.51-1.76
Angus males	7	1.73	1.48-2.02	2.01	1.69-2.23
Angus females	14	1.76	1.49-2.14	1.87	1.60-2.16
Hereford males	15	1.77	1.14-2.19	2.04	1.74-2.20
Hereford females	9	1.65	1.38-1.91	1.79	1.51-1.95
All males	22	1.76	1.14-2.19	2.03	1.69-2.23
All females	23	1.72	1.38-2.14	1.83	1.51-2.16
All animals	45	1.74	1.14-2.19	1.93	1.51-2.23
Standard Error of the Mean for All Animals		± 0.03		± 0.03	

Table 3. Average Blood Urea Nitrogen, Amino Acid Nitrogen and Uric Acid of the Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Urea Ave. (mg./100 ml.)	Urea Range (mg./100 ml.)	Uric Acid Ave. (mg./100 ml.)	Uric Acid Range (mg./100 ml.)	Amino Acid Ave. (mg./100 ml.)	Amino Acid Range (mg./100 ml.)
Lionheart males	3	13.25	10.80-16.03	1.62	1.07-2.67	5.44	4.67-6.50
Lionheart females	1	26.10	---	2.72	---	7.94	---
Prince males	6	14.73	13.15-16.26	1.22	0.80-2.02	6.23	4.33-7.36
Prince females	4	15.27	11.95-18.54	1.47	1.07-1.78	5.87	4.82-6.87
David males	6	16.52	13.45-18.70	1.25	0.93-1.46	6.35	5.59-8.44
David females	4	17.02	15.82-17.76	1.19	1.11-1.29	6.74	5.98-7.59
Angus males	7	14.71	11.37-17.71	1.47	0.89-2.72	5.83	5.23-6.66
Angus females	14	17.05	14.04-22.89	1.82	0.93-2.76	6.42	4.75-10.14
Hereford males	15	14.61	10.80-18.70	1.31	0.80-2.67	6.12	4.33-8.44
Hereford females	9	17.25	11.95-26.10	1.48	1.07-2.72	6.49	4.82-7.94
All males	22	14.64	10.80-18.70	1.36	0.80-2.72	6.02	4.33-8.44
All females	23	17.13	11.95-26.10	1.69	0.93-2.76	6.44	4.75-7.94
All animals	45	15.91	10.80-26.10	1.53	0.80-2.76	6.24	4.33-10.14
Standard Error of the Mean for All Animals		± 0.41		± 0.09		± 0.16	

Table 4. Average Hemoglobin and Hematocrit of Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Hemoglobin Average (gm./100 ml.)	Hemoglobin Range (gm./100 ml.)	Hematocrit Average (percent)	Hematocrit Range (percent)
Lionheart males	3	11.2	10.8-11.5	36.2	35.6-37.0
Lionheart females	1	12.7	---	40.0	---
Prince males	6	11.1	9.7-12.1	37.0	31.7-40.7
Prince females	4	12.6	11.3-14.0	41.7	40.2-43.8
David males	6	11.7	11.2-12.0	38.4	33.9-40.3
David females	4	12.7	11.0-13.7	38.5	31.5-46.2
Angus males	7	12.5	11.7-13.6	41.6	37.1-48.3
Angus females	14	12.5	10.9-14.0	40.6	31.8-46.0
Hereford males	15	11.4	9.7-12.1	37.4	31.7-40.7
Hereford females	9	12.7	11.0-14.0	40.1	31.5-46.2
All males	22	11.7	9.7-13.6	38.7	31.7-48.3
All females	23	12.5	10.9-14.0	40.4	31.5-46.2
All animals	45	12.1	9.7-14.0	39.6	31.5-48.3
Standard Error of the Mean for All Animals		± 0.14		± 0.61	

Table 5. Average Total Red Cell Count and Total White Cell Count of Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Red Cell Counts Average (millions/cu.mm.)	Red Cell Counts Range (millions/cu.mm.)	White Cell Average (hundreds/cu.mm.)	White Cell Range (hundreds/cu.mm.)
Lionheart males	3	6.87	6.32-7.84	98.0	92-104
Lionheart females	1	8.80	---	90.0	---
Prince males	6	7.20	6.04-8.44	84.3	66-94
Prince females	4	7.56	6.88-9.20	96.0	82-130
David males	6	7.22	6.82-7.64	109.0	94-140
David females	4	8.65	7.01-9.60	92.0	78-106
Angus males	7	8.07	7.16-9.81	104.0	80-130
Angus females	14	7.88	6.32-9.46	93.4	78-106
Hereford males	15	7.14	6.04-8.44	96.9	66-140
Hereford females	9	8.18	6.88-9.60	93.6	78-130
All males	22	7.44	6.04-9.81	99.3	66-140
All females	23	8.00	6.32-9.60	93.5	78-130
All animals	45	7.73	6.04-9.81	96.3	66-140
Standard Error of the Mean for All Animals		± 0.14		± 2.31	

Table 6. Mean Corpuscular Volume, Mean Corpuscular Hemoglobin Concentration and Mean Corpuscular Hemoglobin of Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Mean Corpuscular Hb		Mean Corpuscular Volume		Mean Corpuscular Hb Concentration	
		Ave. (micromicrograms)	Range	Ave. (cubic microns)	Range	Ave. (percent)	Range
Lionheart males	3	32.47	31.3-33.1	53.30	45.4-58.6	16.47	13.8-17.9
Lionheart females	1	31.50	---	45.50	---	14.40	---
Prince males	6	33.26	30.4-37.2	51.53	48.0-59.3	15.50	14.3-17.9
Prince females	4	33.30	30.2-35.5	55.75	47.6-59.5	16.83	14.1-19.7
David males	6	32.85	29.2-35.5	53.20	49.3-58.4	16.20	15.5-17.0
David females	4	30.90	28.6-33.7	46.65	44.4-49.2	15.18	13.8-16.9
Angus males	7	33.17	30.4-35.6	51.74	47.4-56.5	15.64	13.9-17.9
Angus females	14	32.54	26.5-37.1	51.74	43.9-58.6	15.96	13.0-18.3
Hereford males	15	32.94	29.2-37.2	52.55	45.4-59.3	15.97	13.8-17.9
Hereford females	9	32.03	28.6-35.5	50.57	44.4-59.5	15.82	13.8-19.7
All males	22	33.01	29.2-37.2	52.29	45.4-59.3	15.87	13.8-17.9
All females	23	32.34	26.5-37.1	51.28	43.9-59.5	15.90	13.0-19.7
All animals	45	32.70	26.5-37.2	51.80	43.9-59.5	15.89	13.0-19.7
Standard Error of the Mean for All Animals		± 0.33		± 0.68		± 0.22	

Table 7. Average Differential Leucocyte Count for Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Lymphocytes Ave. (percent)	Lymphocytes Range	Eosinophils Ave. (percent)	Eosinophils Range	Neutrophils Ave. (percent)	Neutrophils Range	Monocytes Ave. (percent)	Monocytes Range	Basophils Ave. (percent)	Basophils Range
Lionheart males	3	75.3	70-84	3.7	1-5	17.3	11-22	3.7	4-7	---	---
Lionheart females	1	90	---	3	---	4	---	2	---	1.00	---
Prince males	6	77.5	70-87	2.3	1-5	12.8	3-21	7.3	3-9	0.16	0-1
Prince females	4	67.0	56-78	6.8	4-8	22.2	14-34	4.2	4-5	0.00	---
David males	6	75.3	63-87	2.2	1-4	17.5	7-32	5.2	2-10	0.16	0-1
David females	4	76.0	67-87	2.3	1-3	13.7	6-22	7.0	4-10	1.00	1-1
Angus males	7	61.0	53-84	3.0	0-6	28.6	5-38	6.0	4-8	1.57	0-5
Angus females	14	63.2	42-84	3.3	0-12	27.9	10-45	5.5	1-11	0.29	0-2
Hereford males	15	76.2	63-87	2.5	1-5	15.6	3-32	5.7	2-10	0.13	0-1
Hereford females	9	73.6	56-90	4.3	1-8	16.4	4-34	5.2	2-10	0.56	0-1
All males	22	71.4	53-87	2.7	0-6	19.7	3-38	5.8	0-10	0.57	0-5
All females	23	67.3	42-90	3.7	0-12	23.4	4-45	5.4	1-11	0.39	0-2
All animals	45	69.3	42-90	3.2	0-12	21.6	3-45	5.6	1-11	0.49	0-5

Table 8. Average Plasma Protein Fractions for Test Calves at 500 Pounds Body Weight.

Group	Number of Calves	Plasma Proteins: Albumin Ave. (percent)	Albumin Range	Alpha Globulin Ave. (percent)	Alpha Globulin Range	Beta Globulin Ave. (percent)	Beta Globulin Range	Gamma Globulin Ave. (percent)	Gamma Globulin Range	A/G	A/G Range
Lionheart males	3	34.0	32-37	18.0	16-20	14.0	13-15	34.0	30-37	.52	.47-.59
Lionheart females	1	38.0	---	14.0	---	16.0	---	32.0	---	.61	---
Prince males	6	36.0	32-44	17.0	14-19	11.3	9-14	35.0	30-41	.57	.47-.79
Prince females	4	34.5	27-41	15.3	13-19	12.0	8-19	38.3	33-48	.54	.37-.69
David males	6	32.7	30-36	15.7	12-20	14.2	11-18	37.5	33-46	.49	.43-.56
David females	4	38.0	32-48	19.3	19-20	13.5	11-15	29.3	22-35	.63	.47-.92
Angus males	7	38.1	32-42	16.4	12-19	12.7	10-17	32.7	24-37	.62	.47-.72
Angus females	14	38.4	33-43	16.4	11-21	13.2	9-18	32.0	28-40	.63	.49-.75
Hereford males	15	34.3	30-44	16.7	12-20	13.0	9-18	36.1	30-46	.53	.43-.79
Hereford females	9	36.4	27-48	16.9	13-20	13.1	8-19	33.6	22-48	.59	.37-.92
All males	22	35.5	30-44	16.6	12-20	12.9	9-18	35.0	24-46	.56	.43-.79
All females	23	37.7	27-48	16.6	11-21	13.2	8-19	32.6	22-48	.61	.37-.92
All animals	45	36.6	27-48	16.6	11-21	13.0	8-19	33.8	22-48	.58	.37-.92

Figure 1. Correlation between Hemoglobin and Rate of Gain on Test (r=0.40)

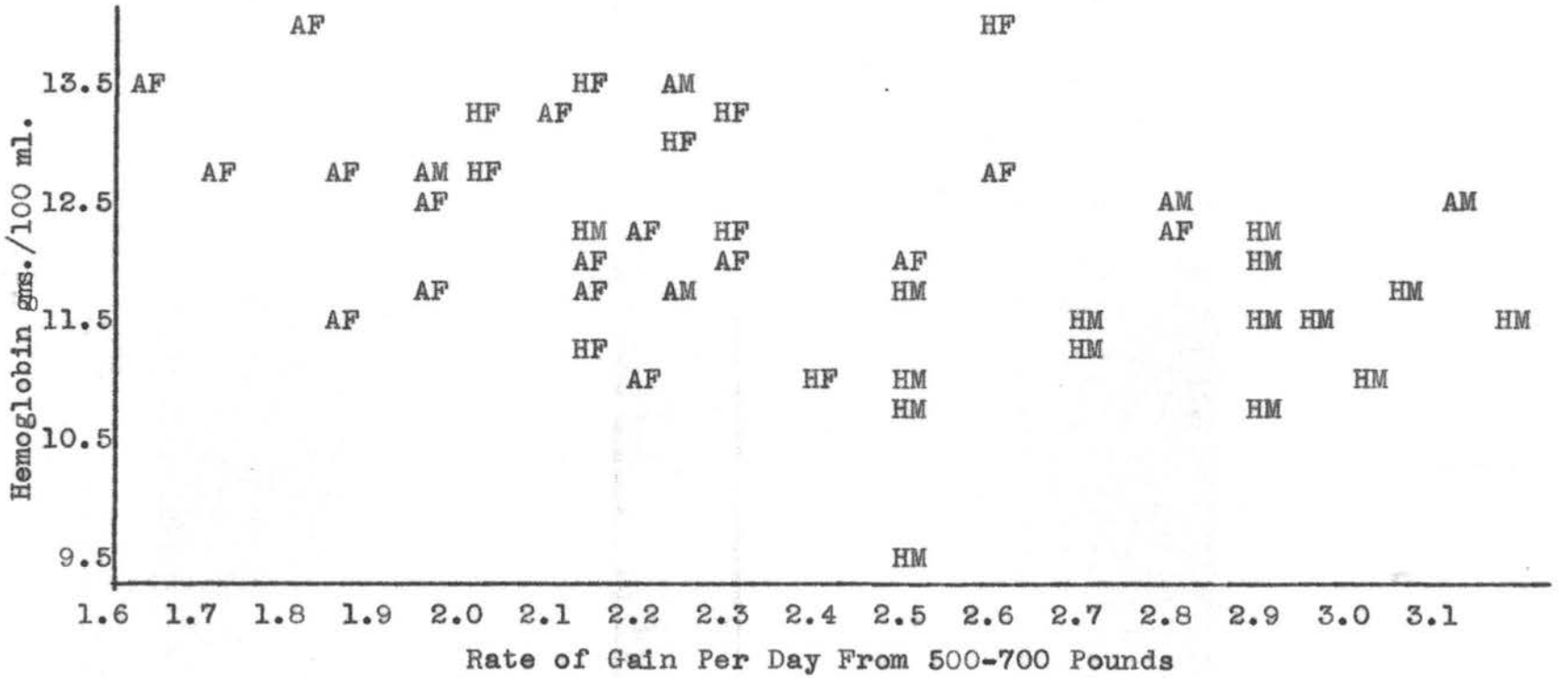


Figure 2. Correlation between Hemoglobin and Pounds of Feed Consumed per 100 Pounds Gain (r = 0.38)

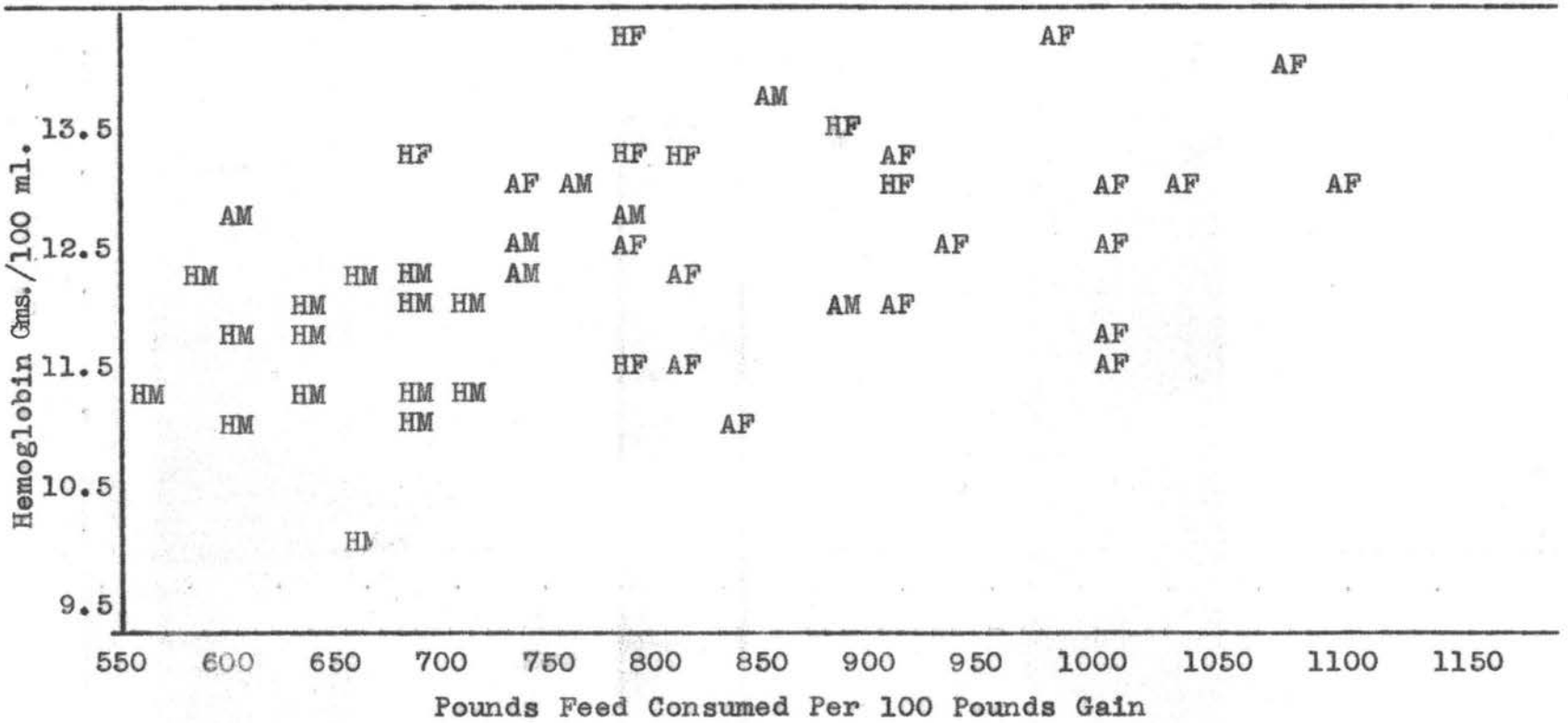


Figure 3. Correlation between Amino Acid Nitrogen and Urea Nitrogen (r = 0.59)

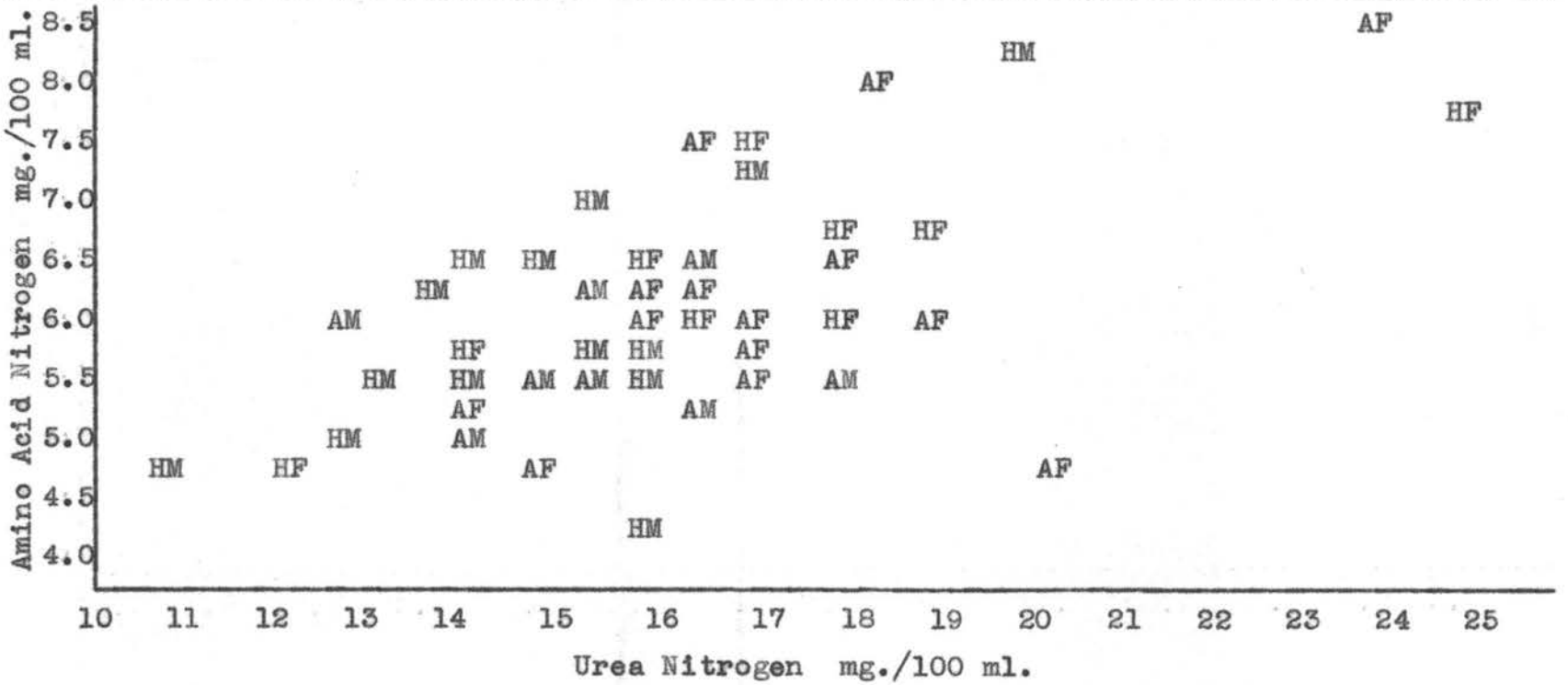
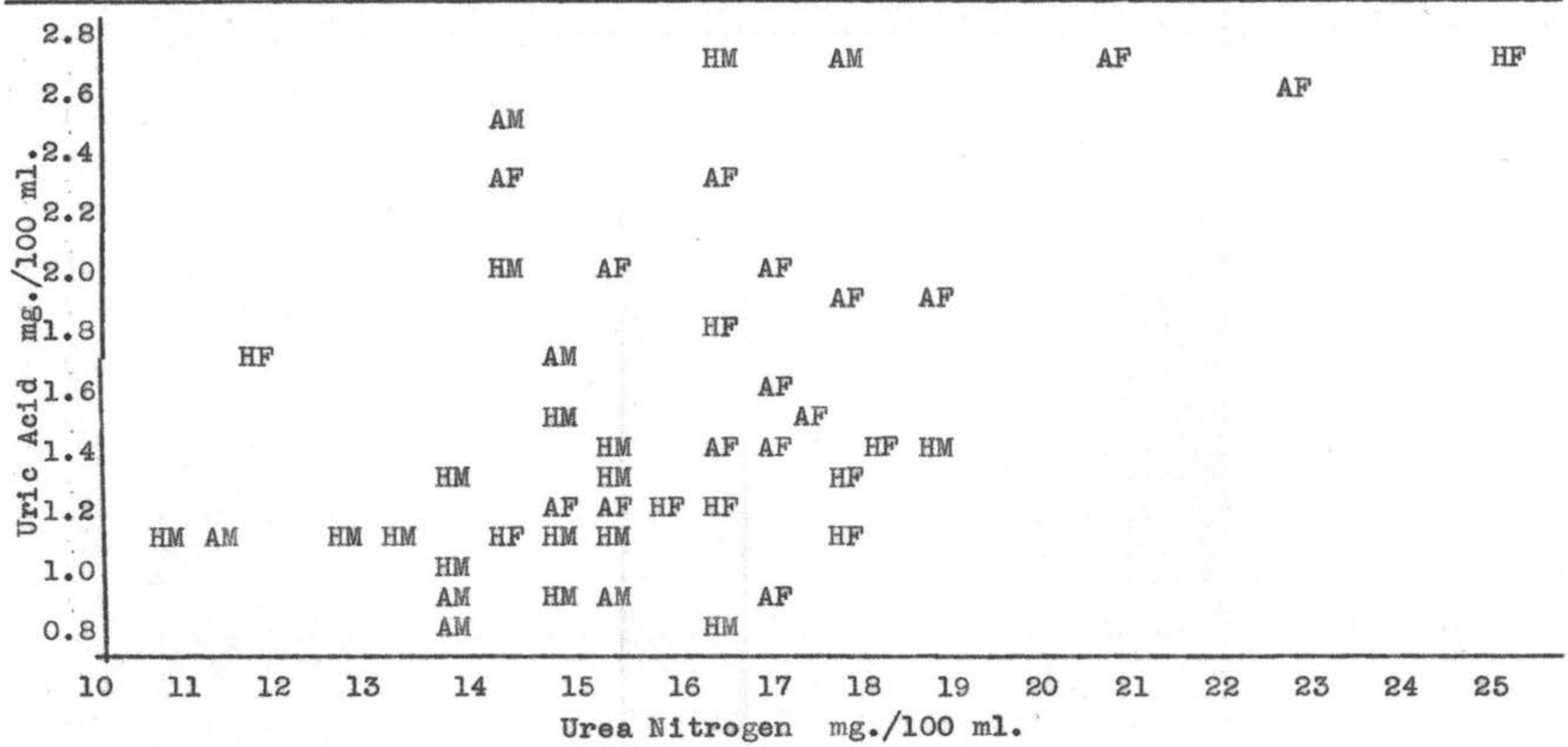


Figure 4. Correlation between Uric Acid and Urea Nitrogen (r = 0.51)



CHAPTER V

DISCUSSION

The primary purpose of the physiological, genetical and environmental studies carried on at the Oregon Agricultural Experiment Station and at similar stations throughout the country has been to improve the productive capacity of farm animals. Similar investigations in the fields of farm crops and agronomy have the same goal in mind, i.e., to improve the production capacity of the soils, and in turn, the feed stuffs and grains grown on these soils. With an ever increasing world population and an ever decreasing acreage of tillable land to support this population, man must of necessity continually strive for improvement in the productive capacity and efficiency of animals and plants of economic importance.

Many of the findings in the present investigation bear only an indirect relationship to the primary objective. Before the productive level of animals can be properly evaluated, many exploratory investigations have to be carried out. For beef cattle to have a high and useful productive level, they must have the ability to produce red meat rapidly and efficiently; therefore, methods of evaluating rate and efficiency of meat production had to come first. Production performance testing of individual beef calves as described in this

investigation has been one of the methods developed and employed at this and other experiment stations to evaluate the productive level of beef animals. The opportunity of handling the animals individually each day on feed test has in itself great merit. Among others, observations on feeding habits of the individual animals, temperament and general physical make up are possible. In addition, the opportunity for taking blood, urine and other components for analysis is greatly enhanced.

With information on rate of gain and efficiency of feed utilization available, the added information afforded by certain anatomical and biochemical data has permitted a study of the association of the anatomical and biochemical data with the production complex. Most investigations to date have been of an exploratory nature to indicate the biological-growth relationships which show the most significant and useful relationships. After determining which relationships are the most promising, attempts should be made to refine the techniques of measuring the biological factors involved.

A. Sex Differences.

Consistent differences have been found between male and female calves with respect to their productive level and certain physiological characteristics. In almost all

instances, male calves exhibited a higher rate of gain per day on feed test than comparable female calves. Observations on an overall basis showed that the male calves had superior gaining ability in the feed lot. In addition, male Hereford and Angus calves showed higher gaining ability in the feed lot than the females of either breed. On a line basis, the differences were not so consistent. The David male calves were the only ones showing a feed lot gaining ability which was statistically significant over the females; however, averages for feed lot gains by sex within lines showed the advantage in favor of the male calves.

Feed required per unit of gain followed the same trend as rate of gain per day on feed test. The male calves showed greater efficiency of feed utilization (less feed per unit of gain) than the comparable female calves.

These trends had been expected since they confirm previous reports from this and other laboratories that males gain more rapidly and more efficiently than females, and that rate of gain and feed consumed per unit of gain are negatively correlated. Price et al. (50) in a previous study calculated a correlation coefficient of -0.86 for the relationship between rate of gain and feed required per unit of gain. In the present study a

correlation coefficient of -0.84 was found. Because of the high correlation between rate of gain and feed per pound of gain there is a fair probability that rate of gain should be correlated with other biological factors showing a correlation with feed consumed per unit of gain, and that the sign of the correlation coefficient should be reversed.

Daily gains from birth to 700 pounds body weight had relationships similar to those of rate of gain per day on feed test and feed per unit of gain. The male calves were superior except in the comparisons between Angus males and females and Prince males and females. Here the males had the higher gaining ability, but the difference was not statistically significant.

In no comparison were male and female calves significantly different in regard to suckling gains.

Variations between sexes for rate and efficiency of gains are conditioned in part by hormonal differences which in turn influence metabolic differences causing variations in growth rate, type of growth and feed conversion efficiency. Weekly intramuscular injections of testosterone (male sex hormone) have resulted in an increase in rate of gain and a decrease in feed required per unit of gain in both heifers and steers, but with heifers showing a marked response to the testosterone,

Burris *et al.* (11). Burris and associates also found that the testosterone-treated heifers had a lower per cent of fat and a higher per cent of protein in the carcass, than control heifers. The thyrotropic hormone content of pituitaries from testosterone-treated calves was greater than that of control calves. Testosterone-treated calves had larger thyroid and adrenal glands than control calves. Thus testosterone is one of the factors inducing the greater rate of gain and greater efficiency of gain in males.

Bartlett (5, p.253), working with dogs, found that injections of testosterone proprionate yielded increased rates of protein synthesis and an increased size of the nitrogen pool over control animals. The anterior pituitary growth hormone also had the capacity to produce marked increases in the size of the nitrogen pool and he suggested that this may be indicative of the mechanism by which testosterone regulates intracellular synthesis of protein.

Few sex differences were found in blood plasma and cellular constituents when analyzed on the overall basis. Only blood urea nitrogen and blood hemoglobin showed statistically significant differences. Urea nitrogen and hemoglobin concentrations were lower in the blood of male calves than of female calves.

When urea nitrogen was analyzed for sex difference from the standpoint of sexes within a breed, both Angus and Hereford males exhibited lower blood urea nitrogen levels than did the corresponding females.

Sex differences in the level of blood hemoglobin were very pronounced. From the overall standpoint male calves had a much lower hemoglobin than the female calves. The same was true for the Hereford calves, i.e., the males had lower hemoglobin levels. In the Angus the same was true, but the sex difference for hemoglobin was not statistically significant. On a line basis, the Prince line follows the general trend, but the David line does not show any sex differences for hemoglobin levels.

Some sex differences showed up in the different lines which were not apparent from the overall and breed comparisons. For example, in the Prince line there was a great deal of difference in the differential leucocyte count. The males showed a higher lymphocyte percentage and much lower percentages in the eosinophils and neutrophils than the females.

Plasma proteins exhibited no statistically significant sex differences, with one exception. The gamma globulin fraction was much higher in the David males than in the David females. There is no explanation for this difference at this time.

B. Breed Differences.

For the herd of cattle on the beef improvement project at Oregon State College the Hereford breed has generally shown superiority in feed lot performance. There has been no advantage for either breed in regard to suckling gains. MacDonald (38) reported consistently higher rate and efficiency values in the Hereford breed when compared to the Angus breed. However, his data were not treated statistically. In the calves involved in this particular study there were some breed differences which were statistically significant. Hereford males showed a sizable advantage in efficiency of feed utilization, but were not superior in any of the remaining performance measurements such as rate of gain on test and gain from birth to 700 pounds body weight. On the other hand Hereford females were superior to Angus females in rate of gain in the feed lot and in feed intake per unit of gain.

There were a number of breed differences noted with respect to components of the blood. Hereford males exhibited much lower levels of blood hemoglobin than the Angus males. The hematocrits and red cell counts were lower in the Hereford males than in the Angus male calves. These differences were not apparent as regards the females. Hereford females and Angus females showed no

significant differences in hemoglobin, red cell count or hematocrit. If both the males and females of one breed differed greatly from the males and females of the other breed as regards the corpuscular differences, it could have been postulated that possibly this difference was influenced by the genetic diversity of the two breeds, because breeders throughout the years have complied with the rather strict rules set up by the breed associations. A plausible empirical explanation may be that the higher red cell count and in turn the higher hemoglobin and hematocrit of the Angus males is related to the more active temperament of Angus males as compared to Hereford males.

Consistent breed differences were found when differential leucocyte counts were compared. Male and female Hereford calves showed significantly higher lymphocyte percentages than the Angus calves and significantly lower neutrophil percentages. This could possibly be explained on a genetic basis.

Hereford males showed a lower average albumin percentage than Angus males; this was also reflected in the albumin/globulin ratio. Albumin percentage and albumin/globulin ratio differences were not found between Hereford and Angus females.

C. Line Differences.

Hereford males showed no line differences in suckling gains or feed lot performance. A few isolated differences were found when the blood values were compared. The only difference which was highly significant occurred when Prince males and David males were compared in respect to their total white cell count. The Prince males had a much lower white cell count.

Comparison between female calves of the different lines was somewhat limited because only one calf was represented in the Lionheart line.

Prince females had much higher suckling gains than David females. In addition they exhibited much higher eosinophil and neutrophil percentages.

D. Correlations of Performance Test and Biological Measurements.

Because of the high negative correlation between feed per unit of gain and rate of gain per day, rate of gain should be correlated with factors showing a correlation with feed consumed per unit of gain; but the sense (positive or negative) of the correlations should be reversed. Also, rate of gain per day from birth to 700 pounds body weight might be expected to be correlated with the same factors as rate of gain from 500 to 700 pounds. However, the measurement from birth to 700

pounds includes gains made during the suckling period before weaning and suckling gains have no relationship at all to feed lot gains.

The high correlation of hemoglobin content with rate of gain and with feed per unit of gain is intimately related to sex and breed differences. Figures 1 and 2 show that sex and breed had a great influence on the negative correlation between hemoglobin levels and rates of gain, and also on the positive correlation between hemoglobin levels and feed requirements per unit of gain. Hereford calves were superior to Angus calves in rate and efficiency of gain (gain per pound of feed); in turn Hereford calves have lower blood hemoglobin levels than Angus calves. On the basis of sex, especially in the Hereford calves, the males were superior in productive efficiency and also had the lower hemoglobin levels than the Hereford females. There is the same relation in the Angus breed. Consequently, the highly significant relationship existing between the level of hemoglobin in the blood and the production complex (that is, both rate of gain and feed per unit of gain) may be mainly a reflection of sex and breed differences, as indicated by the relative distribution of points in Figures 1 and 2.

A similar graphical analysis was applied to the relationship between blood urea nitrogen and the production

complex. In this case it was apparent that interacting sex and breed influences were not the causative factors for the high correlation. This relationship between blood urea nitrogen and the production complex can be explained as less efficient urinary clearance or as a greater rate of production of urea in the more inefficient calves and more efficient elimination or a lower rate of production of urea in the more efficient gainers.

Blood urea concentrations were positively correlated with feed requirements per unit of gain. Hence low blood urea concentration was generally associated with a low feed requirement per unit of gain or with a high gain per unit of feed; and high blood urea concentration was generally associated with a high feed requirement per unit of gain or low gain per unit of feed. High feed requirements per unit of gain imply high maintainance requirements and high maintainance requirements may imply a high rate of protein destruction, and if other factors, such as blood flow, are equal, high concentrations of urea. Thus a high blood urea concentration may reflect a high rate of protein destruction, and a high rate of protein destruction means a low rate of protein accumulation. On this basis blood urea concentration and feed requirements per unit of gain would be positively correlated.

Another possibility which leads to an association between high blood urea concentrations, high blood amino acid concentrations, and high feed requirements per unit of gain, is a deviation in amino acid metabolism, such as might be associated with an inadequate supply of carbohydrate fragments. To make up the deficit in carbohydrate fragments, there would have to be a high rate of deamination of amino acids, and hence a high level of blood amino acid nitrogen and high rates of urea formation, with less of the amino acids available for protein growth.

Feed intake per unit of gain was also negatively correlated with the level of blood uric acid. There was some correlation between rate of gain and blood uric acid but the correlation did not reach the statistically significant level. Williams (69) reported that feed intake had a significant effect on uric acid.

The source of the endogenous uric acid has been placed in the muscles although other evidence has been presented that it may come from destruction of the nuclei in the formation of red blood cells. It may be postulated as a working hypothesis that those animals which are the least efficient have a more active behavior, causing greater muscular activity which is in turn reflected by the higher uric acid level in the blood.

Blood uric acid was also positively correlated with blood urea nitrogen. Urea nitrogen in addition was positively correlated with amino acid nitrogen. Although uric acid and amino acid nitrogen do not show a statistically significant relationship as does urea nitrogen to rate of gain, they do exhibit the same direction in this relationship. It is apparent then that alterations in the levels of these non-protein nitrogenous constituents in the blood tend in the same direction. Also urea, uric acid and amino acid concentrations are similarly related to rate and efficiency of gain.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. Sex, breed and line differences for some plasma and cellular constituents of the blood and of some production characteristics of 45 Hereford and Angus male and female calves on performance test from 500 to 700 pounds body weight have been studied.

2. Average values indicated that male calves had the ability to gain faster and more efficiently than female calves. Male calves exhibited lower levels of blood hemoglobin and urea nitrogen than female calves. Hereford male and female calves show the same differences as in the overall. Angus male and female calves followed except that the difference in the blood hemoglobin level was not statistically significant. Sex differences within Hereford lines showed essentially the same differences as between overall Hereford males and females.

3. Hereford males had an advantage over Angus males in feed efficiency. Rates of gain were not statistically different in the Hereford and Angus males. Hereford females were superior to Angus females on the performance test measurements of rate and efficiency of gain.

Hereford male calves exhibited a lower average of hemoglobin, hematocrit, red cell count and neutrophil percentage and a higher lymphocyte percentage in the cellular constituents of the blood than Angus male calves. Hereford males had a lower average per cent albumin fraction and albumin/globulin ratio than Angus males in the blood plasma proteins. No difference was found between Hereford and Angus females as regards plasma proteins, but the Hereford females did exhibit higher average lymphocyte and lower average neutrophil percentages than Angus females.

4. Line differences were practically non-existent when the male calves were compared. Prince females showed higher suckling gains and higher average eosinophil and neutrophil percentages than David females.

5. Gain and feed efficiency from 500 to 700 pounds body weight was highly correlated with blood hemoglobin and urea nitrogen. The interrelations were greatly influenced by sex and breed.

6. Blood hemoglobin, red cell count and hematocrit showed high correlation indicating that the method and techniques involved in these measurements were satisfactory.

7. Blood urea nitrogen was highly related to blood uric acid and amino acid nitrogen.

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