THE RELATIONSHIP BETWEEN SERUM PROTEINS AND GROWTH IN BEEF CALVES

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INTRODUCTION

Berzelius first called the complex organic nitrogenous substance found in the cells of animals and plants protein (German, Preeminent or first). Now it is known that proteins occupy the central position in the structure and function of living matter. Proteins are associated with all phases of chemical and physical activity that constitute the life of a cell. Proteins serve as the basic constituent of hair, wool, collagen, and an important part of connective tissue. Proteins may be enzymes, hormones, oxygen carriers and they may participate in muscular contractions while still other proteins are associated with the genes, the hereditary factors.

Growth is a term that is used to refer to the numerous ways in which living systems may increase in size, as measured by weights or volumes of the whole animal or part of it. Growth is the constructive or assimilatory synthesis of one substance at the expense of another which undergoes dissimilation (37). Growth is the basis of and is closely related to many productive agricultural processes. One expense in gross productive cost is the transformation of original feed into the final product. To reduce this inherent cost, the animal husbandman has found it possible to accelerate the rate of growth of his animals by employing special techniques of selection. Whether this increased productivity results in greater immediate energetic efficiency depends on the relative acceleration of the productive processes on the one hand and maintenance cost on the other.

Suppose by a wise selection program faster gaining animals with increased efficiency of feed utilization are produced, how will this affect the future health, fertility and longevity of the animal?

This study has as its main objective the determination of relationships among protein fractions and specific gravity of blood serum and the association of these blood constituents with growth rate and economy of feed utilization. Secondary objectives of this study are to determine if serum proteins, serum protein fractions or specific gravity can be used as indices for selecting rapidly gaining cattle at an age prior to production testing. A last objective is to determine if vigorous selection for rapidity of growth and economy of feed utilization has any detrimental effects on the delicate "dynamic state of body constituents".

LITERATURE REVIEW

Normal growth is an integrated process in which a delicate balance is maintained among all of the tissues. The normal increase in body size expressed in terms of weight, follow definite mathematical patterns and can be correlated well with an increase in body protein, a major component of growth.

Neither lack of fat nor lack of carbohydrates can constitute a limiting factor in the growth of an animal provided the total caloric value of the diet is more than adequate for maintenance (28, p. 111). Proteins, however, stand upon a different footing in relation to growth, constituting a large proportion of the dry weight of living tissue. Since proteins are the only abundant nitrogenous constituents of the diet their function as a nitrogen source cannot be filled by any other non-nitrogenous class of foodstuff.

Body protein stores, protein production, protein wear and tear, or protein loss are in a nicely balanced or steady state (29), or a dynamic equilibrium.

Serum Protein

Serum proteins are usually referred to as albumins and globulins. The fraction of serum protein precipitated or salted out by half-saturation with ammonium sulfate was originally referred to as globulin, and the remaining fraction that was precipitated by full saturation with ammonium sulfate was designated as albumin.

Cornelius _et al_. (10) studying 38 Hereford and Angus dwarfs ranging in age from 6 days to 14 months found an average total serum protein value of 6.03 ± 0.9 per cent. From this study they concluded that serum protein values were within normal range for short-headed bovine dwarfs.

Bradish _et al_. (6) studying serum proteins in 51 Devon steers ranging in age from 18 to 30 months found an average total serum value of 6.97 ± 0.53. The data on 30 of the 51 steers had an absolute concentration of 7.0 ± 0.5 g. per 100 ml.

Sprinson and Rittenberg (32) studying rate of interaction of the amino acids of the diet with tissue protein by use of interaction of N^{15} labeled glycine with the body protein in rats and humans, found rates of protein synthesis per Kg. of body weight to be 1.0 and 0.20 grams of nitrogen per day for the rat and human respectively. These data also indicate that almost half (41 per cent) of all protein synthesized in man is associated with liver tissue and plasma proteins.

A total serum protein of 7.60 gms. was given in Albritton's standard values in blood base on the precipitation of protein fractions with salts (serum protein value in gms./100 ml.).

The classical method of estimating the amount of protein in serum is based on a total nitrogen determination by the Kjeldahl method. After a small correction for non-protein nitrogen is made, the nitrogen content is multiplied by 6.25, since serum protein contain about 16% nitrogen. Because Kjeldahl determinations are slow approximate methods which can be performed more rapidly have been devised.

Moore and Van Slyke (23), in 1930 showed that the specific gravity of serum or plasma is essentially a straight line function of the protein content. A gravity error of + 0.0002 entails an error of + 0.06 grams per 100 ml. in the calculated serum protein. The error above may appear to be large but by making standard solutions with specific gravities differing 0.0001, it was found possible to measure gravities to half of these intervals, or to + 0.00005.

Kingsly (17) developed a spectrophotometric method for determining total serum proteins. The diluted serum is treated with special biuret reagent to develop a color. The color developed is compared with a standard with a known amount of serum protein that was determined by the Kjeldahl method. This method will be discussed in more detail in the section on methods and procedures.

Serum Protein Fractions

Howe (19) developed a method for separating the protein of the blood serum into albumin and globulin fractions by precipitating with sodium sulfate which permitted their estimation from Kjeldahl nitrogen determinations. By precipitating serum at different concentrations of sodium sulfate, he obtained fractions he designated as euglobulin, pseudoglobulin and total globulin. Today it is known that what he had was a mixture.

Greenberg (16) described a colorimetric method for determining serum proteins based on the color developed with Folin's phenol reagent and Howe's method of separating the protein by sodium sulfate. This method has the advantage of determining the globulin fraction by subtracting the value for albumin from the total. It is more accurate, however, to determine both albumin and globulin separately.

W. B. Hardy in 1899 discovered that proteins migrate in an electrical field except at the pH of their isoelectric point. Because of this discovery modern electrophoresis techniques have been developed, largely due to the work of Tiselius. The electrophoretic method of analysis is based upon the principle that proteins in solution at pH values above and below their isoelectric points migrate in an electrical field toward the pole bearing a charge opposite to that of the protein. Protein molecules of the same kind move at the same rate and form sharp boundaries in the solution (20; 34).

The theoretical basis of Tiselius method was worked out by Svensson and Dole (12; 33). A modification of this method was used in this study to determine relative percentages of the serum protein fractions.

Albumin

The serum proteins, because of their colloidal osmotic pressure, play an important role in the regulation of the distribution of water in the body; this osmotic pressure is due largely to the albumin fraction (17; 37). Albumin has the smallest molecular weight of the main serum constituents, with a molecular weight of 69,000, whereas the serum globulins have molecular weights from 160,000 to 180,000.

In addition to regulating osmotic pressure, albumin plays a part in the transport of soluble metabolites from one tissue to the other.

Blix *et al*. (5) found that albumin shows little tendency to combine with plasma lipids, but is characterized by forming reversible complexes with the anions and cations of many acid and basic dyes; the anions of alkyl sulfonic acids and fatty acids. It is through these complexes that albumin transports substances in the blood stream.

Smith _et al_. (30) observed marked increases in the mobility and concentration of serum albumin and alpha globulins with increases in age in growing calves.

Bradish _et al_. (6), from data collected on 20 normal Devon steers, found a significant correlation between individual values for serum protein concentration and electrophoretic distribution; the absolute concentration of serum albumin was maintained relatively stable at approximately 3.2 grams per 100 ml. despite much greater changes in the absolute concentration of serum globulins. A mean albumin value of 46.6 ± 4.1 for the 20 steers was observed. The sera were analyzed using the moving boundary technique.

Earlier work based on the precipitation of protein fractions with salts tabulated in standard values in blood (1) gave an albumin value of 3.63 gm. per 100 ml. for cattle serum.

Svensson (33), studying electrophoretic distribution of serum protein expressed as a percentage of the total protein, gave a mean albumin value of 41 per cent.

Cornelius et al. (10), studying serum proteins by a fractionation method in 38 Hereford and Angus dwarfs, concluded that the serum protein values for albumin and the globulin fractions were all within normal range.

An investigation by Wayman and Asdell (35) on bovine nymphomania showed significant variations from control cows in their plasma protein fractions. The plasma protein fractionations were carried out by the sodium sulfate method of Wolfson (40). The protein fractions for normal cows were 3.05, 4.56, 0.65, 1.57 and 2.34 gms. per 100 ml. for albumin, total globulin, alpha globulin, beta globulin and gamma globulin respectively. The nymphomaniac cows had 2.91, 6.41, 0.73, 1.95 and 3.73 gms. per 100 ml. for albumin, total globulin, alpha globulin, beta globulin and gamma globulin respectively.

Globulins

The antibodies of immunology, which constitute an important defense of the body against disease; the metal-binding proteins, which are capable of combining with copper, zinc and iron in order to transport these metals to different tissues; and the mucoproteins, which are used in diagnosing certain diseases, are all associated with the globulins (15, p. 583; 38, p. 639-645).

Allison (3) concluded along with other researchers that the increase in the concentration of alpha and beta globulins, so often associated with disease, may be primarily the result of malnutrition.

Alpha-globulin, a mucoprotein of high carbohydrate content, has been detected in plasma filtrates (38, p. 644). In many metabolic disorders there is a pronounced elevation in the amount of alpha-globulins estimated electrophoretically. The origin and function of alpha-globulins are largely unknown.

A crystalline beta-globulin capable of combining with iron, copper and zinc has been isolated from plasma (38, p. 644). This substance constitutes approximately 3 per cent of the total plasma proteins and has a molecular weight of 90,000. The main function of this metal-binding protein is to transport iron. In such cases as iron deficiency and pregnancy, there is a striking increase in the concentration of beta-globulin.

The antibodies found in the blood are mainly associated with the gamma globulin fraction (18; 30), although some are found in the beta-globulin fraction (8; 14; 38). In the ungulata, gamma globulin is absent in the serum of the new born (30), and therefore no antibodies can be detected in the blood. Ehrlich (38, p. 642) observed that the antibodies in the plasma of this species, ungulata, appear after the young has nursed and received colostrum.

In the ungulata, the placental barriers contain a large number of layers of cells and does not permit the passage of the large antibody molecule from the maternal to the fetal circulation.

Bradish and Brooksby (8) studied the sera of four cattle electrophoretically during the course of injection with two strains of the virus of vesicular stomatitis. An increase in gamma globulin from 3 to 10 per cent above the normal was observed between the third and sixth week following inoculation. The beta globulin fraction increased about 4 per cent but was normal after the first week. The concentration of the albumin fell rapidly to values down to 9 per cent below the normal level.

Bradish _et al_. (7), in an earlier study, showed that changes in the electrophoretic distribution of the normal sera of a single animal are such that differences exceeding 3 per cent in concentration of any component may be regarded as abnormal. In this study they used Devon steers from 18 to 30 months old and observed mean values of 14.0 ± 2.1, 8.9 ± 1.4 and 30.5 ± 4.0 for alpha, beta and gamma globulins respectively.

Sevensson (33), studying fractionations of serum globulins, obtained values of 14.45, 7.45 and 24.95 for alpha, beta and gamma globulins respectively.

Specific Gravity

The specific gravity of serum depends to a large extent on the concentration of the proteins present. Because of the intimate relationship between specific gravity of serum and the serum components, specific gravity can be used to detect, diagnose and treat conditions in which serum proteins are affected (25).

There are numerous methods for obtaining the specific gravity of sera. The falling drop method of Barbour and Hamilton (4) involves the timing of a drop of serum of known size, through a definite distance in a mixture nonmiscible with the fluid. This liquid should have a low viscosity and a specific gravity somewhat below that of the fluid to be tested. It consists of two liquids or substances, one heavier and one lighter than the range of fluids to be tested, so that by adjusting the proportions, the specific gravity of the mixture can be adapted to the expected conditions.

The gradient tube method of Lowry (21) is based on the same principle as the falling-drop method of Barbour and Hamilton (4) but it has certain advantages over the falling-drop method. The advantages of the gradient tube lies in the smallness of sample required, the speed of the analysis, as well as the freedom from influence of temperature or size of drop.

Variations in the falling-drop, gravimetric and gradient tube methods have been used by numerous researchers (4; 21; 23; 25; 36; and others) but all methods show a common disadvantage when used to estimate serum protein concentration because there are constituents in the serum other than protein that influence serum density.

The technique used in the present study consists (25) of letting drops of sera fall into graded series of copper sulfate solution of known specific gravity, and noting whether the drops rise or fall in the solutions. Each drop on entering the solution becomes encased in a copper-proteinate coat, and remains as a discrete drop for 15-20 seconds. The size of the drop needs not be constant and no temperature correction is needed because the temperature coefficient of expansion of the copper sulfate solutions approximates that of the sera. This method is capable of measuring gravities to + 0.00005. The standard copper sulfate solutions are prepared by dilution of a saturated solution.

Reference to serum proteins related to rate and efficiency of growth was given by Price (26) who found a significant correlation between rate of gain per day on feed test and albumin. Price found no other serum protein fraction significantly related to performance test data.

METHOD AND MATERIAL

Data for this investigation were taken from 45 Hereford and Angus calves at the Oregon Agricultural Experiment Station at Corvallis. These animals were from 3 Hereford lines closed to outside breeding since 1950 and one closed Angus line.

These animals were weaned at 400 pounds body weight or by the first week in November when all calves were weaned regardless of weight. After weaning the calves were placed under experimental conditions, where data on rate of gain and economy of feed utilization were collected.

The management procedures recommended by Dahmen and Bogart (11) were followed. The calves were fed a completely pelleted ration consisting of 2 parts chopped alfalfa hay and one part concentrates. This pelleted diet was fed _ad libitum_ twice a day with water available at all times.

The animals were placed on test at 500 pounds body weight at which time they were scored, body measurements taken and they were photographed. This same procedure was followed at 800 pounds body weight at which time the animals were taken off test.

A 10 ml. sample of blood was taken from each animal at 500, 600, 700 and 800 pounds body weight. The blood samples were taken between 10:00 A.M. and 12:00 Noon using a 16 gauge needle and analyses were begun on the blood immediately after collection.

Chemical Analysis

Total Serum Protein

Total serum protein was determined by the method of Kingsley (17, p. 605). This method which entails treating diluted serum with a special biuret reagent was done routinely in the Genetics Laboratory, Withycombe Hall. The color developed was compared photometrically with that of a standard protein solution treated similarly. The Kjeldahl method of protein determination was used to determine the amount of protein in the standard solution.

Serum Protein Fractionation by Paper Electrophoresis

Serum protein fractionation was performed on a Spinco Model R paper electrophoresis apparatus as outlined in the operating Manual (31).

A small sample of serum to be fractionated was applied to paper strips saturated with a commercially prepared electrolyte. The paper strips were attached to paper wicks partially submerged in the electrolyte. The wicks partially submerged in electrolyte connect the ends of the paper strips to positive and negative electrodes.

After allowing sufficient time for migration of the various serum components, the strips were removed from the apparatus and oven-dried. The bands of serum proteins coagulated by the heat were made visible by staining. Concentration of the various components were determined on the basis of light absorption of the stain.

The strips were analyzed by a commercial integrating scanner (31) to determine the relative concentration of the different protein components. The scanner gives the area under the density curve by a corresponding series of pips, every tenth pip being longer than the rest. By drawing a line perpendicular from the density curve to the series of pips, the area under the curve can be obtained by counting the pips. These scanners are provided with optical density cans especially calibrated to plot per cent concentrations directly for any standard dye.

Specific Gravity of Blood Serum

A series of copper sulfate solutions of (17, p. 608) known and varying specific gravity were prepared. These solutions were graded at intervals of 0.001 in specific gravity; the range of the solutions were from 1.015 to 1.035.

A small drop of serum was allowed to drop from a height of about 1 cm. above the solution into one of the standard copper sulfate solutions having approximately the specific gravity expected. A syringe needle was used to drop the serum into the standard copper sulfate solutions. The drop was observed for 10 seconds after having lost its momentum. If the drop rose, it was assumed to be lighter than the test solution; if the drop fell, it was heavier. If it remained stationary after momentum was lost, it had the same specific gravity as that of the standard solution.

Statistical Analyses

The data were analyzed for sex, line, and breed effects by least squares method as outlined by Petersen (24). Means, standard errors, and correlations have been determined.

The least squares model used in this study was as follows:

$$Y_i = \mu + B_j + C_k + e$$

Where Yi = an individual measurement of either

1. specific gravity
2. total serum protein
3. serum albumin
4. serum alpha globulin
5. serum beta globulin
6. serum gamma globulin

7. rate of gain for a particular period
8. feed efficiency for a particular weight period
9. total rate of gain
10. total feed efficiency

and where,

μ = the added effect due to the general mean

B_j = the added effect due to the j^{th} sex

C_k = the added effect due to the k^{th} line

e = the random error term with mean of 0 and variance of 1

Because of the method of collecting the data in the above model, weight was held constant and age was allowed to vary. This model gives no information on the effect of age on the variables studied. To alleviate this condition a second model was constructed with age as a continuous variable. Since the blood samples were taken at definite weight periods, there is in this model a confounding of age with weight. By comparing the analysis of variance of the two analyses, some added information may be obtained as to whether age contributed anything to the differences found.

The least squares model for analysis in which age is included was as follows:

$Yi = \mu + B_j + C_k + A_l + e$

Where Yi = equals an individual measurement of either

1. specific gravity
2. total serum protein
3. serum albumin
4. serum alpha globulin
5. serum beta globulin
6. serum gamma globulin
7. rate of gain for a particular weight period
8. feed efficiency for a particular weight period
9. total rate of gain
10. total feed efficiency

and where,

μ = the added effect due to the general mean

B_j = the added effect due to the j^{th} sex

C_k = the added effect due to the k^{th} line

A_l = a continuous variable; l = age

e = random error term with mean of 0 and variance of 1

EXPERIMENTAL RESULTS

Average values of blood constituents and production traits are tabulated (Tables 1, 2, 3, 4, and 5) by sexes disregarding lines and by sexes within lines at each weight increment 500, 600, 700 and 800 pounds body weight.

Tabulated values (Tables 6, 7, 8, and 9) for the various blood constituents and production traits by weight increments are reported for comparison among lines.

Simple correlations have been computed between each blood constituent and production trait to bring out the relationships among them (Tables 10, 11, 12, and 13).

Comparison Between Sexes

500 Pounds Body Weight

Males in general had significantly higher rates of gains with greater economy of feed utilization (Table 1) than females. The males had an average daily gain of 2.90 lbs./day as compared to 2.49 for the females and required 5.15 pounds of feed per pound of gain as opposed to 5.94 pounds of feed per pound of gain for the females.

Females in general had significantly higher serum specific gravities than males, 1.0261 and 1.0257 respectively, when analyzed by the statistical model allowing age to vary; but when analyzed by the model with age held

TABLE 1

Average Values for Blood Constituents and Production Traits for Calves by Sexes at Each of Four Weights

	500		600		700		800	
	♂	♀	♂	♀	♂	♀	♂	♀
Specific Gravity	1.0257	1.0261[1]	1.0255	1.0256	1.0259	1.0257	1.0252	1.0256[1]
Total Serum Protein	6.80	7.12	6.87	6.89	6.99	6.82	7.05	6.76[2]
Albumin	36.57	35.15	33.85	35.58	31.12	32.73	32.24	33.24[2]
Alpha Globulin	19.66	19.73	21.17	22.31[1]	21.36	23.46[1]	21.74	21.96
Beta Globulin	16.56	18.28	17.51	17.00	18.16	17.86	17.31	17.54
Gamma Globulin	27.14	26.85	26.29	25.35[2]	29.70	25.91[1,2]	28.46	27.26[1,2]
Gain for Period	2.90	2.49[1,2]	2.58	2.26[1]	2.51	2.06[1]	2.48	1.66[1,2]
Efficiency Period	515.96	594.84[1,2]	645.7	845.5[1,2]	788.4	1009.5[1,2]	894.20	1292.4[1,2]
Total Gains	2.49	1.94[1,2]	2.49	1.94[1,2]	2.50	1.94[1,2]	2.50	1.95[1,2]
Total Efficiency	774.03	1043.0[1,2]	774.03	1043.0[1,2]	777.6	1048.5[1,2]	780.2	1026.9[1,2]

TABLE 1, continued

	500 ♂	500 ♀	600 ♂	600 ♀	700 ♂	700 ♀	800 ♂	800 ♀
Age	228.5	249.5	271.2	293.7	306.6	347.1	351.7	401.0
Animals	26	19	26	19	24	17	23	14
Feed Consumption Per Day	15.0	14.8	16.7	19.1	19.8	20.8	22.2	21.4
Total Feed Consumption	19.3	20.2	19.3	20.2	19.4	19.6	19.5	21.3

1 Significant in the model holding weight, sex and line constant and allowing age to vary.

2 Significant in the model holding weight, sex, line and age constant.

3 Serum protein values reported as gms./100 ml. of blood.

4 Albumin and globulin fractions values reported as percentage of total.

5 Gains values reported as lbs./day.

6 Feed efficiency values as feed required per 100 lbs. gain in body weight.

7 These values were reported in the same units for all tables.

as a constant, the difference was removed.

No significant difference was found between sexes in total serum proteins or serum protein fractions. In general females had higher (Table 1) total serum proteins and higher α and B-globulins than the male calves; whereas the male calves had higher albumin and gamma globulin fractions.

Male Hereford calves, in general, had significantly higher daily gains with greater efficiency of feed utilization than female Hereford calves. Hereford male calves gained at an average rate of 2.74 lbs./day with feed requirement at 5.69 pounds of feed per pound of gain. Hereford female calves gained an average of 2.42 lbs./day and required 6.34 pounds of feed per pound of gain (Table 2).

Female Hereford calves, with the exception of the David female calves' specific gravity, had higher specific gravity, higher total serum proteins and higher beta globulin fraction than the Hereford male calves.

Angus males were significantly higher in production traits than Angus females. Angus males had an average daily gain of 3.32 lbs./day and required only 3.85 pounds of feed per pound of gain. Angus females gained 2.42 lbs./day and required 5.43 pounds of feed per pound of gain (Table 2).

In addition, Angus females had lower specific

TABLE 2

Average Values for Blood Components and Production Traits by Sexes Within Lines at 500 Pounds Body Weight

Specific Gravity	Serum Protein	Serum Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gains, Period	Efficiency Period	Total Gains	Total Efficiency
Lionheart Males (9)									
1.0261	6.86	36.41	18.82	16.65	27.93	2.78	626.3	2.52	764.0
Lionheart Females (5)									
1.0274	7.24	35.79	18.84	17.29	27.08	2.43	674.0	1.88	1136.3
Prince Males (8)									
1.0249	6.66	36.66	21.10	16.72	25.39	2.83	535.3	2.56	705.2
Prince Females (2)									
1.0260	7.38	27.91	20.61	18.23	33.24	2.03	671.8	1.88	991.1
David Males (3)									
1.0270	6.60	30.48	19.64	17.65	32.23	2.61	546.0	2.34	850.8
David Females (5)									
1.0256	7.24	36.86	18.25	18.54	26.25	2.81	557.6	2.09	958.7
Angus Males (6)									
1.0255	7.01	39.74	19.01	15.51	25.74	3.32	384.9	2.44	842.5
Angus Females (7)									
1.0254	6.88	35.45	19.02	18.81	25.28	2.42	542.9	1.90	1051.3

gravities, lower serum proteins and lower albumin and gamma globulin fractions than Angus males.

The above data on the Herefords should be in sufficient detail so that a report on the Herefords by sexes within lines is not necessary; but since at this particular weight class, there is a deviation from the generalizations made above, it appears appropriate to report it here. It was stated above that Hereford males in general had higher daily gains than Hereford females. David females, at this weight, had a higher daily gain of 2.81 lbs. per day than David males which only had a daily gain of 2.61. There were 5 females and 3 males in this line.

600 Pounds Body Weight

Males during this period had significantly higher gains per day with greater feed efficiency than females. The difference in daily gains between the males and females was not as large as that during the 500-pound period; males gained 2.58 lbs./day and females gained 2.26. However, the difference between males and females for this period in efficiency of feed utilization was much higher, the males requiring approximately (Table 1) 2 pounds less feed per pound of gain than the females.

Females had higher specific gravities, higher serum proteins and higher albumin, and alpha globulin fractions than males. For the blood components studied, the males were higher than the females only in the beta and gamma globulin fraction.

The females were significantly higher (Table 1) than the males in the alpha globulin fraction. The difference disappeared when the model with age as a constant was used. This indicated that age contributed to the significance of alpha globulin at this weight period.

The gamma globulin fraction of the males was significantly higher than that in the females when the statistical model with age as a constant was used. This would seem to indicate that age has a different effect on alpha and gamma globulin.

Hereford males as in the 500 weight period, made more rapid gains with less feed than Hereford females. Hereford females had lower specific gravities, higher total serum proteins, lower albumin, lower beta globulin fraction and higher alpha and gamma globulin fractions than males.

Angus males gained 2.60 lbs./day as contrasted to Angus females that gained 2.18 lbs./day for this period. For each pound of gain, the Angus females required approximately 3.9 pounds more feed per lb. of gain than Angus males. The feed efficiency for Angus males and females was 5.5 and 9.14 lbs. of feed per pound of gain

TABLE 3

Average Values for Blood Components and Production Traits by Sexes Within Lines at 600 Pounds Body Weight

Specific Gravity	Serum Protein	Serum Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gains, Period	Efficiency, Period	Total Gains	Total Efficiency
Lionheart Males									
1.0254	7.11	34.84	21.28	17.20	24.34	2.58	709.0	2.52	764.0
Lionheart Females									
1.0262	6.83	33.47	23.87	18.33	24.29	1.96	612.8	1.88	1136.3
Prince Males									
1.0252	6.44	32.17	22.10	18.57	27.15	2.53	659.4	2.56	705.2
Prince Females									
1.0230	6.41	31.74	24.04	20.29	23.92	1.91	887.4	1.88	991.1
David Males									
1.0247	6.73	34.11	18.55	16.40	30.84	3.00	605.1	2.34	850.8
David Females									
1.0250	6.79	34.98	22.42	15.82	26.79	2.62	688.5	2.09	958.7
Angus Males									
1.0263	7.13	34.49	21.08	17.11	24.15	2.60	552.9	2.44	842.5
Angus Females									
1.0264	7.14	38.62	19.91	15.96	24.93	2.18	942.3	1.90	1051.3

respectively.

700 Pounds Body Weight

Male calves for this period made average daily gains of 2.51 lbs. while female calves made average daily gains of 2.01 lbs. At 500 and 600 pound body weight periods, the difference between sexes for average daily gain was significant only at the 5% level. During this period, male calves were significantly higher in daily gains (P = .01) (Table 1). The males required 7.9 pounds of feed per pound of gain while the females required 10.1 pounds of feed per pound of gain.

Females had lower specific gravities, lower total serum protein, higher albumin, higher alpha and beta globulin fractions than male calves (Table 1).

Again the alpha globulin fraction was significantly higher in the females than in the males with the difference disappearing when age was held constant.

Also during this weight period, the males had a significantly higher gamma fraction than females when age was held as a constant.

Hereford males had significantly higher daily gains and greater efficiency of feed utilization than Hereford females. Hereford males had an average rate of gain of 2.55 lbs./day while the Hereford females had an average rate of gain of 2.09 lbs./day (Table 4).

TABLE 4

Average Values for Blood Components and Production Traits by Sexes Within Lines at 700 Pounds Body Weight

Specific Gravity	Serum Protein	Serum Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gains, Period	Efficiency Period	Total Gains	Total Efficiency
Lionheart Males									
1.0264	7.02	31.03	22.54	17.16	29.16	2.24	819.2	2.52	764.0
Lionheart Females									
1.0262	6.85	29.23	25.91	19.40	25.05	2.05	1032.8	1.88	1136.3
Prince Males									
1.0253	6.93	33.31	20.73	16.70	29.96	2.91	683.1	2.60	693.4
Prince Females									
1.0250	6.46	23.82	22.06	22.24	31.87	1.95	973.5	1.88	991.1
David Males									
1.0250	6.73	25.00	21.94	23.17	29.91	2.49	774.3	2.34	850.8
David Females									
1.0260	6.79	35.32	21.83	17.12	25.72	2.26	930.2	2.12	952.3
Angus Males									
1.0262	7.15	32.12	19.95	18.63	29.31	2.51	854.4	2.44	842.5
Angus Females									
1.0253	6.94	36.89	23.05	15.62	24.44	1.98	1054.9	1.89	1058.7

Hereford female calves had higher specific gravities, lower total serum protein, lower albumin, beta and gamma globulin fractions and a higher alpha globulin fraction.

Angus male calves had an average rate of gain of 2.5 lbs./day with a feed requirement of 8.5 lbs. per pound of gain. Angus females gained at an average rate of 1.98 lbs./day and required 10.5 pounds of feed per pound of gain.

Angus females had lower specific gravities, lower total serum proteins, higher albumin and alpha globulin fractions and lower beta and gamma globulin fractions than Angus males (Table 4).

800 Pounds Body Weight

Male calves were significantly higher ($P = .01$) in rate of gain and feed efficiency than females. Males grew at an average daily rate of 2.48 lbs. and required only 8.9 pounds of feed per pound of gain, while females grew at an average daily rate of 1.66 lbs. and required 12.9 lbs. of feed per pound of gain (Table 1).

Female calves had higher specific gravities, lower serum protein, high albumin, alpha and beta globulin fractions and lower gamma globulin fraction than male calves.

The specific gravities of the female calves was significantly higher than that of the males but when age

TABLE 5

Average Values for Blood Components and Production Traits by Sexes Within Lines at 800 Pounds Body Weight

Specific Gravity	Serum Protein	Serum Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gains, Period	Efficiency Period	Total Gains	Total Efficiency
Lionheart Males									
1.0255	7.07	31.93	22.29	18.04	27.77	2.83	698.6	2.52	767.2
Lionheart Females									
1.0260	6.70	31.80	20.40	19.13	28.66	1.79	1313.5	2.00	1050.2
Prince Males									
1.0248	6.68	30.44	22.23	16.92	30.41	2.43	821.4	2.61	699.1
Prince Females									
1.0250	6.24	33.17	17.08	21.61	28.14	1.60	1341.4	1.86	1011.7
David Males									
1.0250	7.52	32.36	21.61	17.65	28.37	1.97	1106.7	2.34	850.8
David Females									
1.0247	7.12	31.91	25.51	16.33	26.24	1.56	1276.4	2.03	958.4
Angus Males									
1.0253	7.15	34.41	20.57	16.55	28.46	2.31	996.5	2.44	842.5
Angus Females									
1.0260	6.70	34.75	22.03	16.41	27.52	2.67	1278.1	1.90	1048.1

was held constant the significance was removed.

Total serum proteins and gamma globulin (Table 1) was significantly higher in the males than in the females when age was held constant.

Hereford males (Table 5) made daily gains of 2.41 lbs. while Hereford females gained 1.65 lbs./day. The feed efficiencies for Hereford males and females were 8.7 and 13.1 pounds per pound of gain, respectively.

Hereford females had higher specific gravities, lower total serum proteins, higher albumin, higher beta globulin fraction and lower alpha and gamma globulin fractions than the Hereford males.

Angus males had average daily gains of 2.31 lbs. with a feed requirement of 9.96 lbs. per pound of gain. Angus females grew more rapidly averaging 2.67 lbs./day with a feed requirement of 12.8 pounds per pound of gain (Table 5).

Angus females (Table 5) had higher specific gravities, lower serum proteins, higher albumin, higher alpha globulin fraction and lower beta and gamma globulin fractions than Angus males.

Combination of All Weights

In general male calves had significantly higher daily gains than females for the four weight periods. For the four periods 500, 600, 700, and 800 pounds body weight (Table 1) male calves made an average total daily gain of 2.50 lbs. per day. For the same four periods (500, 600, 700, and 800 pounds body weight) female calves gained an average of 1.95 lb. per day.

Male calves consistently required less feed per pound of gain for the four weight periods than female calves. The males required an average of 7.8 pounds of feed per pound of gain, whereas the female calves required an average of 10.4 pounds of feed per pound of gain.

After the 500 pound weight period, females had higher alpha globulin fractions than males. Likewise, after the 500 pound body weight period, male calves had higher gamma globulin fractions than females. Females had higher specific gravities than males at the 700 pound body weight period.

Hereford males, with the exception of the David males at 500 pounds body weight, were consistently more rapid gainers than Hereford females.

Hereford males consistently had greater efficiency of feed utilization requiring on the average of about 2 pounds less feed per unit of gain than females.

Angus males had consistently higher rates of gains with greater economy of feed utilization than Angus females except at 800 pounds body weight (Table 5).

Angus males at 600 pounds and higher weights consistently had higher beta globulin fractions than Angus females.

Lionheart females were consistently higher in the beta globulin fraction than Hereford males. This was true only of Lionheart females. When all animals were analyzed together by sexes, the males at 600 pounds and higher weights consistently had higher beta globulin fractions.

These data show that on the average, male calves consumed less feed per day than female calves. Male calves consumed an average of 19.4 pounds of feed for the test period, while female calves consumed 20.3 pounds of feed; an average of .93 lbs./day more feed consumed by females than by male calves.

Comparison Between Lines

500 Pounds Body Weight

Of the 3 Hereford lines, the David line grew more rapidly and was more efficient than the Lionheart or Prince lines. The David line had an average daily gain of 2.74 lbs. while (Table 6) the Lionheart and Prince lines had an

TABLE 6

Average Values of Blood Constituents and Production Traits by Lines at 500 Pounds Body Weight

	Lionheart	Prince	David	Angus
Specific Gravity	1.0266	1.0251	1.0261	1.0255
Serum Protein	6.99	6.81	7.00	6.94
Serum Albumin	36.19	34.91	34.54	37.43
Alpha Globulin	19.18	21.00	18.77	19.79
Beta Globulin	16.88	17.12	18.21	17.29
Gamma Globulin	27.63	26.96	28.49	25.50
Gain, Period	2.66	2.67	2.74	2.84
Efficiency, Period	611.1	562.6	553.2	470.0
Total Gains	2.29	2.43	2.18	2.15
Total Efficiency	896.9	762.4	918.3	954.9

average of 2.66 and 2.67 lbs./day respectively. The difference in efficiencies between the David and Prince lines was not too great; the David line required 5.5 lbs. of feed per pound of gain and the Prince line required an average of 5.6 pounds of feed per pound of gain; the Lionheart line was less efficient requiring 6.1.

The Angus line gained the most rapidly and required the least amount of feed per pound gain of the four lines. The Angus line had (Table 6) an average daily gain of 2.84 lbs. and required only 4.7 lbs. of feed per pound of gain.

Means (Table 6) for the various blood constituents are presented in tabular form. There was no consistent line difference at this period for the blood constituents studied.

600 Pounds Body Weight

The David line had an average daily gain of 2.76 and required 6.6 pounds of feed per pound of gain. The Lionheart, Prince and Angus lines were significantly lower with an average daily gain of 2.36, 2.41, 2.37 lbs. respectively; and required 7.6, 7.1, 7.6 pounds of feed per pound of gain respectively. The Lionheart line and the Angus line had approximately the same feed efficiencies and rates of gain (Table 7).

During this weight period (Table 7), the Lionheart

TABLE 7

Average Values of Blood Constituents and Production Traits by Lines at 600 Pounds Body Weight

	Lionheart	Prince	David	Angus
Specific Gravity	1.0257	1.0248	1.0249	1.0264
Serum Protein	7.01	6.43	6.77	7.14
Serum Albumin	34.35	32.09	34.65	36.71
Alpha Globulin	22.20	22.49	20.97	20.84
Beta Globulin	17.60	18.92	16.04	16.49
Gamma Globulin	24.31	26.51	28.31	25.65
Gain, Period	2.36	2.41	2.76	2.37
Efficiency, Period	759.5	705.0	657.2	762.5
Total Gains	2.29	2.43	2.18	2.15
Total Efficiency	896.9	762.4	918.3	954.9

line and the Angus line had significantly higher specific gravities and total serum protein than the Prince and David lines. The other values for the blood constituents for this period are also reported in Table 7.

700 Pounds Body Weight

In the two preceding periods, of the 3 Hereford lines, the David line has been the most rapid in gain and required less feed per pound of gain. During this period the Prince line gained more rapidly and was more efficient than the other 3 lines, Lionheart, David and Angus. The Prince line made gains of 2.67 lbs./day while the Lionheart, David and Angus lines made gains of 2.17, 2.36 and 2.24 respectively (Table 8). To make this gain, the Prince line required an average of 7.5 lbs. of feed per pound of gain and the Lionheart, David and Angus lines required 8.9, 8.6 and 9.5 respectively.

Values of blood constituents for this period can be found in Table 8.

TABLE 8

Average Values of Blood Constituents and Production Traits by Lines at 700 Pounds Body Weight

	Lionheart	Prince	David	Angus
Specific Gravity	1.0263	1.0252	1.0256	1.0257
Serum Protein	6.96	6.82	6.76	7.04
Serum Albumin	30.39	30.94	30.90	34.50
Alpha Globulin	23.70	21.06	21.87	21.50
Beta Globulin	17.95	18.09	19.71	17.12
Gamma Globulin	28.19	30.44	27.51	26.87
Gain, Period	2.17	2.67	2.36	2.24
Efficiency, Period	895.5	755.7	863.4	954.7
Total Gains	2.29	2.42	2.21	2.17
Total Efficiency	896.9	770.1	908.8	950.6

800 Pounds Body Weight

From 500 to 700 pounds body weight, the Lionheart line on the average made slower gains than any of the other 3 lines. During the present period, the Lionheart line made significantly higher gains than the other lines with an average daily gain of 2.48 pounds. The Prince line was second with 2.31, the Angus line third with 2.17 while the David line was last with 1.76 pounds per day.

Although the Lionheart line on the average was the most rapid in rate of gain, the Prince line had a lower average feed requirement of 8.9 as opposed to 9.6, 11.4 and 11.9 pounds of feed per pound of gain for Lionheart, Angus and David lines (Table 9).

The Lionheart and Angus lines had significantly higher specific gravities than the Prince and David lines.

The Lionheart and Angus lines had higher serum protein concentrations than the Prince line for this period, but not the David line. It is possible that since specific gravity and serum protein concentration show a straight line relationship, blood constituents other than serum proteins contributed to the higher specific gravity of the Angus and Lionheart lines during this period.

Combination of All Weight Periods

The Angus line during the first period had a higher

TABLE 9

Average Values of Blood Constituents and Production Traits by Lines at 800 Pounds Body Weight

	Lionheart	Prince	David	Angus
Specific Gravity	1.0257	1.0248	1.0248	1.0257
Serum Protein	6.95	6.62	7.32	6.92
Serum Albumin	31.88	30.83	32.13	34.64
Alpha Globulin	21.66	21.49	23.56	21.30
Beta Globulin	18.41	17.59	16.99	16.48
Gamma Globulin	28.07	29.23	27.31	27.57
Gain, Period	2.48	2.31	1.76	2.17
Efficiency, Period	966.1	895.7	1191.6	1137.3
Total Gain	2.35	2.50	2.18	2.17
Total Efficiency	861.9	743.8	904.6	945.3

rate of gain with greater economy of feed utilization than any of the other 3 lines. During the second period the Angus line was only superior to the Lionheart line in rate of gain and the two lines had the same efficiencies. The third period was interesting in that the Angus line was still gaining more rapidly than the Lionheart line (Table 8) but the Lionhearts which gained an average of 0.07 lbs./day less than the Angus line were more efficient. In the fourth period the Angus line made higher daily gains than the David line and was only more efficient than the David line.

The David line made better gains than the Lionheart or Prince for the first 3 weight periods. During the fourth period the David line had the lowest test gain and was the least efficient of the four lines.

The Prince line had a higher rate of gain than the Lionhearts in the first period, than the Lionheart and Angus during the second period, than the Lionheart, David and Angus during the third period and than the David and Angus during the fourth. The feed efficiency for the Prince line varied with the average rate of gain. The periods when they had superior gains, they (Prince animals) also had a lower feed requirement.

The Lionheart line consistently throughout the first

3 weight periods had lower rates of gain than the other 3 lines. However, in the last weight period, the Lionheart line had a significantly higher rate of gain than the other 3 lines (Prince, David and Angus). The Lionheart line on the average was less efficient in their feed utilization than the Prince or David lines.

When the total rate of gain and the total feed efficiency are considered, one can see at a glance (Tables 6, 7, 8 and 9) that the Prince line made more rapid gains than the Lionhearts and significantly higher than the David and Angus lines. At the same time, the Prince line required less feed per unit of gain than the Lionheart, David or Angus line.

The Lionheart line consistently had higher specific gravities than the other 3 lines. The Lionheart line also had higher serum protein than the other 3 lines except at 800 pounds (Table 9) body weight when the David line had the highest average for total serum protein.

Correlations

Simple correlations between blood constituents and production traits were calculated to determine the relationship among them. Simple correlation coefficients were dtermined at 500, 600, 700, and 800 pounds body weight.

500 Pounds Body Weight

A significant negative correlation of -.831 was found between gain per day and feed required per unit of gain ($P < 0.01$).

A positive correlation of 0.391 was found between feed efficiency for this period and feed efficiency for the entire 500-800 lb. period ($P < 0.05$).

Significant negative correlations of albumin with alpha, beta, and gamma globulin were found.

600 Pounds Body Weight

There was a significant negative correlation of -0.638 ($P < .01$) between rate of gain and feed per unit of gain. Rate of gain was also (Table 11) positively correlated ($r = 0.701$) with total gain from 500 to 800 pounds body weight and negatively correlated ($r = 0.577$) with total feed per unit gain from 500 to 800 pounds body weight.

There was a significant negative correlation ($r = 0.638$) between rate of gain and feed required per unit gain.

Feed efficiency for this period was significantly correlated with total feed efficiency ($P < 0.01$).

Gamma globulin was significantly correlated with both total rate of gain and total feed required per unit gain

TABLE 10

Correlation Coefficients Among Blood Constituent and Production Traits at 500 Pounds Body Weight

	Specific Gravity	Total Protein Serum	Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gain for Period	Efficiency Period	Total Gain	Total Efficiency
Specific Gravity		.219	-.044	-.203	.170	.051	.137	.047	.204	.019
Total Protein Serum			.247	-.281	-.221	.083	.236	-.059	.082	.054
Albumin				-.388*	-.668**	-.487**	.189	-.133	.078	-.008
Alpha Globulin					.121	-.303*	.052	-.121	-.143	.112
Beta Globulin						-.097	-.022	.138	-.050	-.080
Gamma Globulin							-.288	.007	-.050	.010
Gain for Period								-.831**	.261	-.298*
Efficiency Period									-.238	.391*
Total Gain										-.829**
Total Efficiency										

* P = 0.05

** P = 0.01

TABLE 11
Correlation Coefficients Among Blood Constituent and Production Traits
at 600 Pounds Body Weight

	Specific Gravity	Total Protein Serum	Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gain for Period	Efficiency Period	Total Gain	Total Efficiency
Specific Gravity		.314*	.205	-.220	-.334*	.116	-.009	-.146	-.068	.098
Total Serum Protein			.202	-.333*	-.186	.160	-.047	-.025	-.159	.094
Albumin				-.509**	-.607**	-.327*	.085	.109	.005	-.131
Alpha Globulin					.310*	-.338*	.199	-.103	.242	-.152
Beta Globulin						-.117	-.005	-.065	.071	.133
Gamma Globulin							.255	.042	-.403**	.297*
Gain for Period								-.638**	.701**	-.577**
Efficiency Period									-.515**	.412**
Total Gain										-.829**
Total Efficiency										

* P = 0.05

** P = 0.01

($P < .01$). There was a significant correlation between alpha globulin and beta and gamma globulin ($P < 0.05$). Albumin was negatively correlated with alpha ($r = -0.509$), beta ($r = -0.607$) and gamma ($r = -0.327$) globulin. Albumin was highly negatively correlated with alpha and beta globulin ($P < .01$).

Serum protein was negatively correlated with alpha globulin ($P < .05$), (Table 11). Specific gravity was positively correlated with total serum protein and negatively correlated with beta globulin ($P < 0.05$).

700 Pounds Body Weight

A significant negative correlation ($r = -0.550$) was found between rate of gain and feed required per unit of gain for this period. A positive correlation between gain for this period and total gain ($r = 0.425$) was observed along with a negative correlation of gain for this period and feed required per unit gain for the total period from 500 to 800 lb.

Feed required per unit of gain for this period was negatively (Table 12) correlated with total gain ($r = -0.485$) and positively correlated with feed required per unit of gain for the total period ($r = 0.530$).

Specific gravity was positively correlated with total

TABLE 12

Correlation Coefficients Among Blood Constituent and Production Traits at 700 Pounds Body Weight

	Specific Gravity	Total Serum Protein	Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gain for Period	Efficiency Period	Total Gain	Total Efficiency
Specific Gravity		.452**	-.077	-.036	-.229	.246	.381*	-.187	.408**	-.326*
Total Serum Protein			.099	-.097	-.230	.089	.066	-.034	.044	-.106
Albumin				-.106	-.648**	-.044	-.010	.022	.015	-.060
Alpha Globulin					.079	-.601**	.078	.164	-.184	.110
Beta Globulin						-.001	-.145	.220	-.216	.313*
Gamma Globulin							.057	-.295	.220	-.213
Gain for Period								-.550**	.425**	-.363*
Efficiency Period									-.485**	.530**
Total Gain										-.837**
Total Efficiency										

* P = 0.05

* P = 0.01

serum protein ($r = 0.452$) with rate of gain for this period ($r = 0.381$) and with total gain ($r = 0.408$).

Specific gravity was negatively correlated with total feed required per unit gain.

Albumin was correlated with beta globulin, having a negative correlation of -.648 which was significant at $P < 0.01$.

Alpha globulin was negatively correlated with gamma globulin ($r = -0.601$). Beta globulin was negatively correlated with feed required per unit of gain for the total period.

800 Pounds Body Weight

Rate of gain (Table 13) was correlated with feed required per unit of gain for this period ($r = -.823$) with total gains ($r = .690$) and with feed required per unit of gain for the total period ($r = -0.684$).

Feed required per unit of gain for this period was negatively correlated with total gains ($r = -0.581$) and positively correlated ($r = 0.774$) with feed required per unit gain for the total period.

Total serum proteins had a significant negative correlation with rate of gain for this period.

Albumin was negatively correlated with both alpha ($r = -0.543$) and gamma ($r = -0.662$) globulin. However,

TABLE 13

Correlation Coefficients Among Blood Constituent and Production Traits at 800 Pounds Body Weight

	Specific Gravity	Total Serum Protein	Albumin	Alpha Globulin	Beta Globulin	Gamma Globulin	Gain for Period	Efficiency Period	Total Gain	Total Efficiency
Specific Gravity		.310	.123	-.292	.168	.040	.051	-.130	-.046	-.148
Total Serum Protein			-.137	-.061	.282	.093	-.353*	.214	-.239	.175
Albumin				-.543**	-.247	-.662**	.320	-.198	.385*	-.212
Alpha Globulin					-.376*	-.021	-.125	.140	-.148	.135
Beta Globulin						-.022	-.095	.097	-.097	-.001
Gamma Globulin							-.298	.113	-.344*	.188
Gain for Period								-.823	.690**	-.684**
Efficiency Period									-.581**	.774**
Total Gain										-.857**
Total Efficiency										

* P = 0.05

** P = 0.01

albumin had a significant positive correlation with total rate of gain from 500 to 800 pounds body weight.

Alpha globulin was negatively correlated with beta globulin ($P < 0.05$). Gamma globulin was significantly correlated with total gains.

Combination of All Weights

Rate of gain for each period was consistently negatively correlated with feed required per unit gain for the same period. With the exception of the 500 pounds weight period, rate of gain for each period was consistently positively correlated with total rate of gain from 500 to 800 pounds body weight. Rate of gain for each period was consistently negatively correlated with total feed required per unit of gain from 500 to 800 pounds body weight.

Feed efficiency for each period was consistently positively correlated with total feed efficiency. Feed required per unit gain was consistently negatively correlated with total rate of gain from 500 to 800 pounds body weight, with the exception of 500 pounds weight period.

Total rate of gain from 500 to 800 pounds body weight was negatively correlated with total feed required per unit gain from 500 to 800 pounds body weight ($r = -0.84$).

Specific gravity was generally positively correlated with total serum protein, although it was not significantly correlated with total serum protein at 500 pounds body weight. At 600 and 700 pounds body weight the correlation between specific gravity and serum protein was significant. At 800 pounds body weight specific gravity had a correlation of .310 with total serum protein which approached significance ($P < .05$).

Albumin was negatively correlated with alpha and gamma globulin except at 700 pounds body weight. Albumin was negatively correlated with beta globulin for the first three weight periods, but not at 800 pounds body weight.

Alpha globulin was negatively correlated with gamma globulin at the first three periods.

DISCUSSION

Walter B. Cannon developed a concept of physiological homeostasis and defined this phenomenon as the totality of steady states maintained in an organism through the coordination of its complex physiological processes. In other words, homeostasis is the property of the organism to adjust itself to variable conditions, or the self-regulatory mechanisms of the organisms which permit it to stabilize itself in fluctuating inner and outer environments. Needless to say, final answers to the problems of physiological homeostasis are by no means available. The existence of biological feedback mechanism is recognized, the largely mechanistic basis of their operation is accepted, but their increasingly complex development presents the focal problem in adaptation. In this discussion various factors, genetic and environmental, have been evaluated for their influence on growth; growth to a degree is an indication of adaptation.

Sex Difference

The data presented show certain consistent sex differences in the production traits and in some of the physiological constituents studied. Male calves consistently had higher daily gains than female calves.

Similarly, male calves required less feed to make a unit of gain. A negative correlation of -.84 was found between rate gain and feed required per unit of gain for the total period which tends to support or to be consistent with the above statements.

That males are faster gainers and more efficient feed utilizers than comparable females was expected since studies made at this station and at other stations have shown similar results (2; 11; 22; 26; 27; 39).

There were in this study two deviations from the above generalization that males consistently gain more rapidly than females; at 500 pounds body weight the David females gained 0.2 lb. per day more rapidly than the David males and at 800 pounds body weight Angus females gained 0.36 lb. more per day than Angus males. At the present time, there is available no explanation for these deviations.

At 500, 600 and 800 pounds body weight the female calves had blood with higher specific gravities than that of the male calves. At 500 and 800 lbs. body weight the specific gravity of blood from the females was significantly higher than that of the males when the statistical model allowing age to vary was used. However, when the statistical model holding age as a constant was used, the significance was removed. The difference in the specific gravity of blood from the females compared with that of males at 500 and 800 pounds body weight can be attributed to the difference in age of the males and females. The female calves were an average of 21 days older than the male calves at 500 pounds body weight and an average of 49.3 days older at 800 pounds body weight. If the difference in specific gravity between males and females was due to sex, one would expect a high correlation (negative or positive) between specific gravity and total gains or between specific gravity and total feed efficiency since sex was held constant in the analysis. On the contrary, the correlations between specific gravity and total gains and between specific gravity and total feed efficiency was low indicating that very little of the variance was accounted by the statistical model holding sex constant and allowing age to vary. Therefore the appearance of a difference between the specific gravities of males and females can possibly be attributed to a difference in the ages of the males and females at any weight period.

Plasma protein fractions exhibited no significant sex differences, except that the gamma globulin fraction of the males was higher than that of the females when the statistical model holding age as a constant was used. Price (26) reported in his study of plasma proteins that the gamma globulin fraction in the blood of the David males was significantly higher than that in David females. In the statistical analysis in which the constants for sex were determined at each of the four weights and age was permitted to vary, there was no significant sex difference. However, when the constants for both age and sex were estimated at each of the four weights, there was a significant sex difference at 600, 700 and 800 pounds body weight. Age and weight are confounded because the animals become older and increase in size simultaneously. The correlation coefficient between gamma globulin and total gains was significant at 600 and 800 pounds body weight. Negative correlations of -.403 and -0.344 were found between gamma globulin at 600 and 800 lbs. respectively and total gains. Since a significant sex difference was found when age was held constant along with sex and weight, it seems possible that the difference in specific gravities between the two can be attributed to the difference in ages between the male and female calves; or the sex difference may be due to a weight-age interaction.

An observation of interest in this study was that daily gains did not increase but decreased as calves grew from 500 to 800 pounds body weight. Feed required per unit of gain increased markedly as calves grew from 500 to 800 pounds body weight. These changes were more pronounced in females than in males. The average daily gain of males decreased 0.42 lb. per day during the period from 500 to 800 pounds body weight whereas in the females the average daily gain decreased 0.83 lb. per day from 500 to 800 pounds body weight. Likewise the feed required per unit gain increased more markedly in females than in males. An increase in feed required per unit of gain of 6.97 lbs. in females and 3.78 lbs. in males was observed. However, the increase in feed consumed per day from 500 to 800 pounds body weight of 7.2 lb. was the same for males and females. For the total period (500 to 800 pounds body weight) the females consumed an average of 0.93 lbs./day more feed than the males.

Line Difference

Consistent line differences were not observed in this study, but some interesting differences were noted. At 500 pounds body weight the Angus line made more rapid gains with a greater efficiency of feed utilization than either of the three Hereford lines. At the end of the feed test period, however, the Angus line was superior only to the David line which had a predominance of females, 5 female to 3 male calves. The Lionheart line varied in the opposite direction; that is, the Lionheart line had a slower rate of gain than either of the other 3 lines

(Prince, David, and Angus) for the first 3 weight periods, in the fourth it was somewhat higher than the Prince line (the Prince line had a larger number of males than females) and significantly higher than the David or Angus line.

The difference in the growth habits of the Angus and Lionheart calves may well be attributed to past selection pressures. Since selection in the past history of the Angus cattle has been for early maturity as appears evident by the smaller mature size of Angus as compared with Herefords, the tapering off of growth rate from 500 to 800 pounds body weight may well be due to maturity. At the present time the only possible explanation for the growth pattern of the Lionheart line might be that because of the large size they attain, growth may be slower in early life and increase as they approach 800 lb. in body weight. In other words, the Lionheart line of cattle reaches a mature weight at a later age than the other 3 lines. Brody (9, p. 501) found that in farm animals an inflection in the growth curve takes place when about 30 per cent of the mature weight is reached, which corresponds to about 6 months in cattle. The point of inflection is the time of puberty and the time of maximum velocity of growth (transition from increasing to decreasing growth velocity). Then, what appears to be a different growth pattern in the two lines may be a difference in time of puberty. An alternate explanation for the difference in growth pattern between the Angus line and Lionheart line could be in the ability to digest a high roughage ration. Bogart (unpublished data) observed at the Oregon Experimental Experiment Station (1949-1951) that the Angus line performed better during the latter part of the experimental period than the Lionheart line, when the ration was largely hay in the first part and equal hay:grain in the latter part of the test period. This would lead one to believe that the Angus line has the ability to grow rapidly and efficiently on concentrates while the Lionheart line has the ability to grow rapidly on roughages. In the above observation, there is a confounding of time of maturity with diet. The composition of the diet could have contributed to differences in growth patterns or to the time of maturity, or both. Since, at the present time, the composition of the diet (2/3 roughage to 1/3 concentrates) is the same throughout the experimental period, one would anticipate that the time of maturity is the most plausible reason for the difference in growth patterns.

Because of the disproportion of males to females in the Prince line and in the David line, a realistic line difference cannot be obtained.

Correlations of Blood Constituents With Growth

Growth is the aspect of development concerned with the increase in living substances or protoplasm and includes three processes (1) cell multiplication, (2) cell enlargement and (3) incorporation of material from the environment (9, p. 486). The inclusion of non-protoplasmic substances, such as blood serum, is an increase by incorporation of material from the environment, which is not regarded as true growth. Yet operationally, from the standpoint of quantitative measurements of growth of the organism as a whole, there must be a consideration of these non-protoplasmic inclusions as part of the growth process, if they are reversible.

An average negative correlation of -.84 was found between total gains and total feed required per unit of gain. This agrees with other studies at this experiment station (2; 26; 27; 39).

There were no consistent correlations between the blood constituents and the production traits. However, specific gravity was consistently positively correlated with total serum protein. This correlation of specific gravity with total serum protein is substantiated by the findings of Moore and Van Slyke (23) when they showed that the specific gravity of blood serum was a straight line function of its protein content.

Alpha globulin was consistently negatively correlated with gamma globulin. This is in accordance with the sex difference found, because males had higher gamma globulin and lower alpha globulin than females. Albumin was consistently negatively correlated with the globulin fractions.

Bradish et al. (7) observed from blood studies on Devon steers that there was a compensatory relationship between albumin and the globulins and within the globulins. They found that when the albumin increased the globulin decreased and vice versa. The same was true between the globulin fractions. The values were expressed as percentage of the whole. The present study indicates that within the globulin fractions, when there was an increase in alpha globulin there was a decrease in gamma globulin and vice versa. This relationship was supported by significant negative correlations from 500-700 pounds body weight between alpha and gamma globulins. Beta globulin was positively correlated with alpha and negatively correlated with gamma globulin, but the compensatory relationship between beta and gamma was not as apparent as between alpha and gamma globulins. The small correlation between beta and gamma globulin supports this observation.

The origin and function of alpha globulin is unknown

(38, p. 644), but since there is a compensatory relationship between the relative amounts of alpha and gamma globulin in the blood, it is possible that the function of alpha globulin is relative to the need of the animal for the production of antibodies, since the gamma globulin fraction contains the bulk of the proteins for immunity; and, conversely, the production of antibodies is probably related to the stress conditions the animal suffers. In other words, the relative production of alpha or gamma globulin varies with the animal's particular need for the function performed by either of the two. This is partially supported by evidence from blood studies with Ungulata in general, and perhaps with other species, that the blood of the young at birth is void of gamma globulins. There is probably little need for antibodies by the fetus. However, at the present, there is no explanation for the sex difference found in the amount of alpha and gamma globulins found in the serum of male and female calves. But (38, p. 649), it has been shown that in metabolic disturbances there is a pronounced elevation in amount of alpha globulin estimated electrophoretically. These data showing females with higher alpha globulin than males are consistent with the performance data where females are more inefficient utilizers of their feed than males. Since the alpha globulin values reported for females were within the normal range for beef cattle, there is no evidence of abnormal metabolic disorders for the females. Since females are slower gainers and less efficient feed utilizers than males, there could possibly be an inherent difference between males and females in metabolic efficiencies.

SUMMARY AND CONCLUSIONS

1. Production traits and blood serum constitutents have been studied on 45 calves from three genetically different Hereford lines and one Angus line at 500, 600, 700 and 800 pounds body weight. Statistical analyses were performed to determine the sex and line differences.
2. Data from this study indicated that male calves had higher feed test gains than females and required less feed per unit of gain. At 500 and 800 pounds female calves had significantly higher serum specific gravities than male calves. The difference in specific gravity seems to be attributed to a difference in age between male and female calves. When age was held constant, the gamma globulin fraction of the males was significantly higher than that of the females.
3. Angus calves were the most rapid gainers at 500 pounds and required less feed per unit gain than calves of either of the 3 Hereford lines. At the end of the feed test period, Angus calves were only gaining faster than calves in the David line that was largely females. The Lionheart line made the slowest gains for the first 3 weight periods and then made the most rapid gains during the last period. This indicates a

difference in age of maturity between the two lines.

4. There were no consistent correlations between the blood constituents and the production traits. However, specific gravity and total serum protein were consistently positively correlated. Albumin was consistently negatively correlated with the globulin fractions. Alpha globulin was consistently negatively correlated with gamma globulin.

   At 600 and 800 pounds, gamma globulin was significantly negatively correlated with total gains. At 500, 700 and 800 pounds, alpha globulin was negatively correlated with gains for the total period and positively correlated with feed required per unit gain for the total period.

5. Male calves on the average were 21 days younger at the beginning of the feed test period and 49.3 days younger at the end of the feed test period than female calves.

6. Male calves made more rapid gains than female calves because of greater efficiency of feed utilization rather than because they consumed more feed. Females in this study ate an average of 0.93 lbs./day more than the males.

7. The blood constituents and production traits were influenced by differences in ages. When age was held constant in the analyses certain differences that

existed when age was allowed to vary disappeared, and in some cases where no differences were noted when age was allowed to vary there appeared significant differences when age was held constant.

8. Daily gain decreased as calves grew from 500 to 800 pounds body weight. Feed required per unit gain increased markedly as calves grew from 500 to 800 pounds body weight. These observations were more pronounced in females than in males.

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