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Rate and Efficiency of Gains in Beef Cattle

V. Serum Phosphatases of Growing Hereford and Angus Calves

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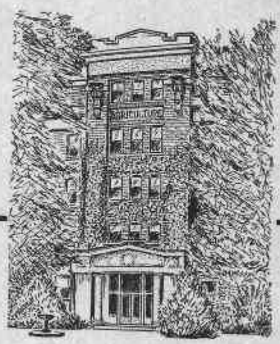

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Rate and Efficiency of Gains in Beef Cattle

V. Serum Phosphatases of Growing Hereford and Angus Calves

Introduction

During the last twenty years, much research has been carried out in the field of beef cattle improvement. Attention has been focused on the rate of gain and the economy of gain of young growing animals as indices of their own and their progeny's future performance. Knapp and Nordskog (1946) have shown by their estimates of heritability that these criteria were eminently suited to this purpose. However, the determinations of rate of gain and economy of gain over an adequate period of time are expensive both in time and labor. Many workers have been exploring the possibility of some other criteria of excellence which will obviate the necessity for a prolonged feeding period.

Performance testing of beef calves has been carried out at the Oregon Agricultural Experiment Station over a period of years. Concurrently with this testing program there have been developed studies of the various constituents of the blood and urine (MacDonald *et al,* 1956, Price *et al,* 1957, Williams, 1955). The present study was undertaken to determine whether the serum phosphatases in the blood of young growing cattle might be of value as a predictive tool in indicating high rate and economy of gain. Because of the close functional relationship between the phosphatases and inorganic phosphate, blood and serum inorganic phosphates were included.

Review of Literature

Serum Alkaline Phosphatase.

Blood serum contains a mixture of small amounts of phosphatases of which the principal components are the phosphomonoesterases. Alkaline phosphatase or phosphomonoesterase I (Sumner and Myrback, 1950) is present in high concentration in the blood serum. It is found in all animal cells with the exception of hyaline cartilage and the walls of blood vessels. However, the tissues which contain relatively large amounts of this enzyme are the zones of growth of the bones of young animals, the intestinal mucosa, kidney cortex, and lactating mammary gland. To a lesser extent, liver and brain also contain large amounts of alkaline phosphatase. Since the alkaline phosphatases from various tissue sources can be distinguished from each other to some degree but that of serum and of bone have similar properties, it has been suggested that the bulk of the alkaline phosphatase in the serum is derived from osseous sources (Moog, 1946). It has been further postulated that the serum alkaline phosphatase is excreted in the bile (Gutman *et al*, 1940).

Fell and Robison (1929, 1930, 1934) demonstrated that there was intense alkaline phosphatase activity immediately preceding the calcification of bone. Further studies established that bone alkaline phosphatase was one of the most important elements in the mineralization of bones and teeth, especially in periods of growth. Furthermore, alkaline phosphatase has been found in high concentration wherever rapid calcification was in progress.

The blood phosphates are believed to be fixed as esters in the bones where the phosphatase can then liberate them readily by means of hydrolysis. This permits the rapid and abundant formation of tricalcium phosphate, the renewal of Ca^{++} ions in the osseous fluids being assured by diffusion of calcium from the blood to the intercellular osseous fluids.

Kunkel *et al* (1953) examined the serum alkaline phosphatase activity of European and Brahman cross cattle and found a lowering of phosphatase activity with age from 3.4 micromole units per liter of serum (6.8 Bodansky units per 100 ml.) for 8 to 14 month old European cattle to 1.5 micromoles (3.0 Bodansky units) for cows 3 to 9 years of age. They also examined the possibility of correlations between phosphatase level at the beginning and end of the feeding trial and feed-lot gain in a limited number of beef bulls. They found a correlation coefficient of -0.19 between *initial* phosphatase level and feed lot gain and a coefficient of -0.56 between *final* phosphatase level and feed lot gain. In studies with Brahman male and female cattle carried out over a period of three years, Fletcher *et al* (1956) could find no consistent relationship between serum alkaline phosphatase activity and subsequent gain.

Serum Acid Phosphatase.

Minimal amounts of acid phosphatase or phosphomonoesterase II (Sumner and Myrback, 1950) are present in serum. Acid phosphatase does not have the same tissue distribution as alkaline phosphatase. The prostate of man and of the higher apes is very rich in this enzyme, and the spleen and liver contain appreciable quantities of acid phosphatase. However, in other mammals, the prostate does not contain large amounts of acid phosphatase. In general, it seems that the tissues possessing intense alkaline phosphatase activity, except for the liver, are low in acid phosphatase.

Both phosphatases are commonly found in the cytoplasm of growing, regenerating, and secreting cells in which protein synthesis is in progress. There appears to be a correlation in such cells between the content of ribose nucleic acid and alkaline phosphatase. In tissues which carry on much traffic in glycogen, acid phosphatase is possibly provided to prevent bone formation (Moog, 1946).

Blood and Serum Inorganic Phosphate.

Phosphates are concerned in the maintenance of a proper reaction in the blood, are of great importance in the formation of bone and teeth, are necessary in the maintenance of a normal calcium concentration in the blood, and play an essential part in carbohydrate metabolism, in the transfer of energy in muscle contraction, and in secretory cell activity (Dukes, 1947). Inorganic phosphate is the source material for the organic phosphates formed in the body (Goodman and Gilman, 1941).

Blood phosphorus is determined as phosphate but is calculated and reported as elemental phosphorus. The inorganic phosphate exists as $HPO_4^{=}$ and $H_2PO_4^{-}$ in a ratio dependent on the pH. All the blood inorganic phosphate appears to be ultrafiltrable if the calcium and phosphorus are within normal limits (West and Todd, 1956).

During the last thirty years much attention has been focused on the important role phosphate plays in bovine nutrition and metabolism. Green and duToit (1927) were among the first to study dietary requirements for phosphorus and observed that the cause of "styfsiekte" and the associated allotriophagia was a deficiency of phosphate in the feed. Eckles, Becker, and Palmer (1926) also were among the early workers studying phosphate nutrition. They found that lack of phosphate was the cause of a deficiency syndrome in the dairy cattle of Minnesota.

Numerous workers have studied the blood inorganic phosphate levels of normal bovines. Long *et al* (1952) report levels of from 7.5 mg. per 100 ml. plasma at six months of age to 4.5 mg. per 100 ml. plasma at 30 months in a group of Hereford and Shorthorn heifers over a period of two years. Haag and Jones (1935) recorded the inorganic phosphate levels in the blood plasma of dairy cattle of different ages in Oregon with levels of from 7.7 mg. per 100 ml. at six months to 5.2 mg. per 100 ml. at 4 years of age.

Methods and Procedure

Data presented in this investigation were taken from 44 beef calves, maintained in the Oregon Agricultural Experiment Station beef herd at Corvallis, Oregon, which had been subjected to performance test investigations. They were of two breeds, Aberdeen Angus and Hereford, the latter consisting of three closed lines. The calves were all born in the spring of 1956, and after weaning in October and November were transferred to the test pens. Here they were individually fed twice daily with weekly weights and feed consumptions being recorded. The ration used consisted of pellets containing two parts chopped alfalfa and one part concentrate (Nelms *et al.* 1953). The calves were kept on test until they reached 800 pounds live weight and their rate of gain and feed economy calculated for the period during which they grew from 500 to 800 pounds.

Upon reaching 800 pounds, an oxalated blood sample of 10 ml. was obtained together with another of 30 ml. without oxalate. The non-oxalated sample was allowed to clot and, after centrifugation, the serum was drawn off. The blood samples were collected from the test calves between 9:00 and 10:00 a.m. Blood inorganic phosphate was determined on the oxalated sample immediately. The serum was frozen overnight and the serum inorganic phosphate and alkaline and acid phosphatases were determined the following day.

The method for determination of inorganic phosphate was that of Fiske and Subbarow (1925) with the following modification: The photometer was set at 650 millimicrons and the samples were made up to a final volume of 15 ml. instead of 10 ml.

Alkaline phosphatase was determined by the method suggested by Hawk, Oser, and Summerson (1951). The incubation procedure of Bodansky was used with modifications to permit the use of the method of Fiske and Subbarow for the determination of phosphate liberated. The procedure described by Shinowara, Jones, and Reinhart modified by Hawk, Oser, and Summerson to permit the use of the Fiske and Subbarow phosphate method was chosen for the determination of serum acid phosphatase.

The means, standard errors, ranges, regression coefficients and correlations have been obtained according to statistical techniques outlined by Li (1957). The data have been presented with subdivisions to allow comparisons between sexes, breeds, or lines.

Experimental Results

The information compiled on each animal includes average rate of gain on feed test (rate of gain), average feed consumed per 100 pounds gain, and age in days at 800 pounds body weight. Analyses were made for blood inorganic phosphate, serum inorganic phosphate, serum alkaline phosphatase, and serum acid phosphatase.

Tabulations of the data have been made to facilitate comparisons between sexes within breeds, sexes between and within lines, and an overall sex comparison. Gross correlations have been assembled between the various blood constituents and feed lot performance data. Differences between means for group comparisons have been tested statistically by Fisher's t test, with significant differences being chosen at probabilities of 0.05 or less. The data on rate of gain on test, feed consumption per 100 pounds gain, and age at 800 pounds have been presented in Table 1 for reference purposes.

1. *Serum Alkaline Phosphatase.*

The mean level of serum alkaline phosphatase of all animals was 5.31 Bodansky units per 100 millilitres (Table 2). Bodansky units of phosphatase activity are given by the number of mg. of inorganic phosphate liberated from 0.5 percent buffered beta-glycerophosphate in one hour at 37°C by 100 millitres of serum. All males had a mean serum alkaline phosphatase level 1.76 Bodansky units per 100 millilitres higher than that of the females (Table 4). Angus males had an average level 1.92 Bodansky units higher than that of the Angus females. Both differences were significant at the 1 percent level. The other male groups (Hereford, Lionheart, Prince, and David lines) had higher serum alkaline phosphatase levels than those of the corresponding female groups but the differences were not statistically significant.

Hereford females had a mean alkaline phosphatase level 1.31 Bodansky units higher than the Angus females ($P<0.05$).

2. *Serum Acid Phosphatase.*

The mean acid phosphatase level for all animals was 0.42 Bodansky units per 100 ml. serum (Table 2). On the average, male calves were found to have levels 0.19 Bodansky units higher than female calves ($P<0.01$). Hereford male calves also had average acid phosphatase levels 0.31 Bodansky units per 100 ml. serum in excess of the Hereford females ($P<0.01$). Breed and line differences were not significant, Hereford males having a mean acid phosphatase level 0.28 Bodansky units higher than Angus males (Table 4). Hereford females had levels averaging 0.02 Bodansky units less than Angus females.

Table 1. Average Rate of Gain and Feed Consumption per Unit of Gain of Hereford and Angus Calves from 500 to 800 Pounds Body Weight.

Group	Number of calves	Daily rate of gain		Feed per 100 lbs. gain		Age at 800 lbs.	
		Average	Range	Average	Range	Average	Range
		pounds	*pounds*	*pounds*	*pounds*	*days*	*days*
Lionheart males	5	2.73	(2.34-3.03)	703	(639-752)	350	(311-379)
Lionheart females	1	2.06		937		378	
Prince males	5	2.91	(2.25-3.78)	621	(554-669)	349	(325-387)
Prince females	6	2.27	(1.99-2.89)	842	(722-937)	394	(369-447)
David males	5	2.83	(2.57-3.12)	704	(644-742)	359	(346-377)
David females	5	2.14	(1.83-2.68)	947	(784-1002)	424	(353-474)
Hereford males	15	2.83	(2.25-3.78)	676	(554-752)	352	(311-387)
Hereford females	12	2.20	(1.83-2.89)	894	(722-1002)	405	(353-474)
Angus males	5	2.64	(2.28-2.93)	775	(659-851)	352	(329-372)
Angus females	12	1.96	(1.66-2.24)	1044	(895-1238)	403	(345-461)
All males	20	2.78	(2.25-3.78)	701	(554-851)	352	(311-387)
All females	24	2.08	(1.66-2.89)	969	(722-1238)	404	(345-474)
All animals	44	2.40	(1.66-3.78)	847	(544-1238)	380	(311-474)
Standard error of the mean for all animals		0.047		16.78		4.40	

TABLE 2 (a). AVERAGE SERUM ALKALINE PHOSPHATASE AND SERUM ACID PHOSPHATASE LEVELS OF HEREFORD AND ANGUS CALVES AT 800 POUNDS BODY WEIGHT.

Group	Serum alkaline phosphatase (Bodansky units/100 ml. serum)		Serum acid phosphatase (Bodansky units/100 ml.)	
	Average	Range	Average	Range
Lionheart males	6.68	(3.63-9.64)	0.58	(0.42-0.85)
Lionheart females	4.53		0.66	
Prince males	6.66	(5.14-8.68)	0.64	(0.40-1.21)
Prince females	6.04	(3.20-9.04)	0.39	(0.01-0.63)
David males	6.01	(3.82-8.93)	0.55	(0.09-0.80)
David females	4.24	(2.69-6.10)	0.28	(0.19-0.42)
Hereford males	6.45	(3.63-9.64)	0.59	(0.09-1.21)
Hereford females	5.16	(2.69-9.04)	0.28	(0.01-0.66)
Angus males	5.77	(3.83-8.60)	0.31	(0.12-0.54)
Angus females	3.85	(2.65-5.71)	0.30	(0.18-0.44)
All males	6.27	(3.63-9.64)	0.52	(0.09-1.21)
All females	4.51	(2.65-9.04)	0.33	(0.01-0.66)
All animals	5.31	(2.65-9.64)	0.42	(0.01-1.21)
Standard error of the mean for all animals	0.26		0.031	

Blood and Serum Inorganic Phosphate Levels.

In general, differences between the sexes in blood and serum inorganic phosphate levels were not found to be significant with the exception of that between Angus males and females in which the males had significantly higher blood and serum inorganic phosphate levels ($P<0.05$). Prince males had a mean blood inorganic phosphate level 0.69 mg. per 100 millilitres less than that of the Prince females ($P<0.05$).

In a comparison between the blood inorganic phosphate levels of the male calves of the various Hereford lines, the David calves had levels significantly higher than those of the males of both Lionheart and Prince lines (Table 4).

TABLE 2 (b). AVERAGE BLOOD AND SERUM INORGANIC PHOSPHATE LEVELS OF HEREFORD AND ANGUS CALVES AT 800 POUNDS BODY WEIGHT.

Group	Blood inorganic phosphate (mg. P/100 ml./ blood)		Serum inorganic phosphate (mg. P/100 ml./ serum)	
	Average	Range	Average	Range
Lionheart males	5.12	(4.48-5.56)	7.97	(7.43-8.38)
Lionheart females..	4.47		6.74	
Prince males	4.77	(4.16-5.29)	7.96	(7.44-9.50)
Prince females	5.46	(4.99-6.01)	8.18	(7.16-9.70)
David males	5.83	(5.37-6.19)	8.06	(6.63-9.23)
David females	5.36	(4.72-6.43)	8.16	(6.71-9.15)
Hereford males	5.24	(4.16-6.19)	8.00	(6.63-9.50)
Hereford females ..	5.33	(4.47-6.43)	8.05	(6.71-9.70)
Angus males	5.47	(4.90-6.00)	8.16	(7.85-8.66)
Angus females	4.92	(4.22-6.09)	8.44	(5.38-9.20)
All males	5.30	(4.16-6.19)	8.04	(6.63-9.50)
All females	5.13	(4.22-6.43)	7.75	(5.38-9.70)
All animals	5.21	(4.16-6.43)	7.88	(5.38-9.70)
Standard error of the mean for all animals	.09		0.14	

Correlations Between Performance and Blood Constituent Data.

Gross correlations were calculated on the performance test information and the blood data to determine possible relationships. Rate of gain was found to be negatively correlated with feed per unit of gain and with age at 800 pounds body weight. It was positively correlated with both serum phosphatases. All correlations were significant at the 1 percent level (Table 5).

Feed consumption per unit of gain was positively correlated with age at 800 pounds body weight and negatively correlated with both serum phosphatases ($P<0.01$).

Serum inorganic phosphate was positively correlated with blood inorganic phosphate ($P<0.05$).

TABLE 3. DIFFERENCES BETWEEN THE MEAN RATES OF GAIN, FEED PER UNIT OF GAIN, AND AGE AT 800 POUNDS OF HEREFORD AND ANGUS CALVES.

Group Comparison	Difference between means		
	Rate of gain	Feed	Age
	(lbs. per day)	(days)	(lbs./100 lbs. gain)
Prince males v. females	+0.64*	–221†	–45*
David males v. females	+0.69†	–243†	–65*
Hereford males v. females	+0.63†	–218†	–53†
Angus males v. females	+0.70†	–269†	–51†
All males v. females	+0.70†	–268†	–52†
Males			
Lionheart v. Prince	–0.18	+ 82*	+ 1
Lionheart v. David	–0.10	– 1	– 9
Prince v. David	+0.08	– 83*	–10
Hereford v. Angus	+0.19	– 99†	0
Females			
Prince v. David	+0.13	–105†	–30
Hereford v. Angus	+0.24	–150†	+ 2

* Significant at 0.05 level. † Significant at 0.01 level.

The positive sign means that the group of animals listed first had a value greater than that listed second. For example, in the first line, Prince males had a 0.64 pound per day greater rate of gain, ate 221 pounds of feed less per 100 pounds of gain and were 45 days younger on reaching 800 pounds than the Prince females.

In order to examine whether line and sex differences had been contributing to the high correlations between the serum phosphatases and rate of gain, intra-class correlations between these constituents and rate of gain were calculated. They are presented in Table 6. For comparison, intra-class correlations between feed consumption per unit of gain and age at 800 pounds body weight and rate of gain are also presented. From these dissections of the data, it will be readily seen that feed consumption per unit of gain is highly negatively correlated with rate of gain, especially in the case of females ($P<0.01$). Similarly, with the exception of the Prince males which influence the Hereford male correlation, age at 800 pounds is negatively correlated with rate of gain.

Table 4. Difference Between the Mean Blood Inorganic Phosphate, Serum Inorganic Phosphate, and Serum Phosphatase Levels of Hereford and Angus Calves.

Group Comparison	Difference Between Means			
	Serum alkaline phosphatase	Serum acid phosphatase	Blood inorganic phosphate	Serum inorganic phosphate
	(BU/100 ml.)	(BU/100 ml.)	(Mg./100 ml.)	(Mg./100 ml.)
Prince males v. females	+0.62	+0.25	–0.69*	–0.22
David males v. females	+1.77	+0.27	+0.47	–0.10
Hereford males v. females	+1.29	+0.31†	–0.09	–0.05
Angus males v. females	+1.92†	+0.01	+0.55†	+0.72*
All males v. females	+1.76†	+0.19†	–0.08	+0.29
Males				
Lionheart v. Prince	+0.02	+0.06	+0.35	+0.01
Lionheart v. David	+0.67	+0.03	–0.71*	–0.09
Prince v. David	+0.65	+0.09	–1.06†	–0.10
Hereford v. Angus	+0.68	+0.28	–0.23	–0.16
Females				
Prince v. David	+1.80	+0.11	+0.10	+0.02
Hereford v. Angus	+1.31	–0.02	+0.41	+0.61

* Significant at 0.05 level. † Significant at 0.01 level.

In a consideration of the intra-class correlations between serum alkaline phosphatase and rate of gain, there are variable values for the males, both Prince and Angus males showing negative correlations, while all other groups of males showed positive correlations. However, the female calves all showed positive correlations with rate of gain.

By contrast, the correlation of +0.37 between serum acid phosphatase and rate of gain was found to be composed of both negative and positive correlations within the different classes. There did not appear to be any consistent pattern.

While the numbers of animals involved in the calculation of these correlations on an intra-class basis is quite small (*circa* 5), the consistent pattern of correlations between feed consumption per unit of gain, age at 800 pounds, and rate of gain indicate that they have some value. On this basis it would seem that there is a definite and consistent correlation between serum alkaline phosphatase and rate of gain in *the female calves*, a correlation somewhat independent of breed and line differences.

Regression Coefficients Between Performance and Blood Constituent Data.

Regression coefficients were calculated for the data studied (Table 5). However, only those where the correlation coefficients were found to be significant will be discussed.

RATE OF GAIN AND PHOSPHATASES. A 0.1 pound increase in rate of gain was associated with an increase of 0.223 Bodansky units per 100 ml. serum in alkaline phosphatase activity and of 0.018 Bodansky units in acid phosphatase activity (Table 5). As the average alkaline phosphatase activity was 5.31 Bodansky units this means an increase of 4.1 percent in the ability of serum to alter the concentrations of monophosphate esters when a pH of 8.6 is provided. As the average activity of acid phosphatase was 0.42 Bodansky units, the increase of 0.018 units of activity for each 0.1 pound increase in the rate of gain is equivalent to a 4.2 percent increase in the ability of serum to alter the concentration of monophosphate esters when a pH of 5.0 is provided.

PHOSPHATASES. Acid phosphatase increased by 0.039 Bodansky units for every increase of one Bodansky unit in alkaline phosphatase, while serum inorganic phosphate increased by 0.63 mg. per 100 ml. serum for every increase in blood inorganic phosphate of 1 mg. per 100 ml. blood.

The intra-class regression coefficients (Table 7) support the relationship indicated by the correlation coefficients of acid and alkaline phosphatases on rate of gain in female calves. The slope of the regression line for alkaline phosphatase on rate of gain is remarkably constant when the small number of calves in each group is considered ($b = 5.52$, 3.08, 4.73, 1.43, and 4.20). The regression of acid phosphatase on rate of gain in the female groups did not yield as consist-

TABLE 5. CORRELATION AND REGRESSION COEFFICIENTS INVOLVING RATE OF GAIN, FEED PER UNIT GAIN, AGE AT 800 POUNDS, SERUM ALKALINE PHOSPHATASE, SERUM ACID PHOSPHATASE, BLOOD INORGANIC PHOSPHATE, AND SERUM INORGANIC PHOSPHATE.

Ordinates	Rate of gain	Feed unit gain	Age at 800 lbs.	Serum alkaline phosphatase	Serum acid phosphatase	Blood inorganic phosphate	Serum inorganic phosphate
Rate of gain		-0.87†	+0.62†	+0.54 †	+0.37†	+0.16	+0.15
Feed unit gain ..	-323.		+0.74†	-0.56 †	-0.48†	-0.24	-0.24
Age at 800 lbs. ..	-51.5	+0.16		-0.41 †	-0.41†	-0.04	-0.18
Serum alkaline phosphatase ..	+2.23	-0.0062	-0.20		+0.33	-0.21	+0.11
Serum acid phosphatase ..	+0.18	-0.0006	-0.0024	+0.039		+0.08	+0.14
Blood inorganic phosphate	+0.20	-0.0008	-0.0005	-0.006	+0.21		+0.39*
Inorganic phosphate	+0.30	-0.0013	-0.0045	+0.54	+0.57	+0.63	

* Significant at 0.05 level. †Significant at 0.01 level.

The values on the top right hand are the correlation coefficients while those in the bottom left are the regression coefficients.

Table 6. Correlations of Feed Consumption per Unit Gain, Age at 800 Pounds, Serum Alkaline Phosphatase, and Serum Acid Phosphatase with Rate of Gain Between 500 and 800 Pounds Body Weight.

Group	Feed consumption per unit gain	Age at 800 pounds	Serum alkaline phosphatase	Serum acid phosphatase
Lionheart males	-0.83*	-0.19	+0.46	+0.69
Prince males	-0.58	+0.81*	-0.44	-0.50
Prince females	-0.88†	-0.48	+0.83†	-0.08
David males	-0.54	-0.32	+0.68	+0.16
David females	-0.96†	-0.96†	+0.81*	+0.73
Hereford males	-0.55*	+0.33	+0.99	-0.14
Hereford females	-0.81†	-0.63*	+0.78†	+0.12
Angus males	-0.75*	-0.32	-0.74	+0.50
Angus females	-0.80†	-0.61*	+0.24	-0.27
All males	-0.60†	+0.22	-0.01	+0.07
All females	-0.81†	-0.56†	+0.71†	+0.13
All animals	-0.87†	-0.62†	+0.54†	+0.37†

* Significant at 0.05 level. † Significant at 0.01 level.

ent a pattern as for the alkaline phosphatase (b = 0.01, +0.06, +0.07, -0.01). However, when these values are compared with the wide variation in values for the male groups, it is possible that there may be some fairly consistent relationships between acid phosphatase and rate of gain as well as that demonstrated between alkaline phosphatase and rate of gain.

Discussion

The data presented require comparison with the literature, and discussion from the aspects of sex variation, breed and line variation, and certain physiological conclusions arising from the information assembled.

Comparisons with literature

The performance data indicate that, within the four categories of Hereford and Angus male and female calves, Hereford males were the fastest and most efficient gainers of the four groups while the

Table 7. Regression Coefficients of Feed Consumption per Unit Gain, Age at 800 Pounds, Serum Alkaline Phosphatase, and Serum Acid Phosphatase on Rate of Gain Between 500 and 800 Pounds Body Weight.

Group	Feed consumption per unit gain	Age at 800 pounds	Serum alkaline phosphatase	Serum acid phosphatase
Lionheart males	–172.0	– 20.3	+0.06	+0.42
Prince males	– 50.6	+ 37.6	–0.17	–0.29
Prince females	–198.9	– 43.9	+5.52	–0.01
David males	– 93.1	– 16.8	+0.08	+0.20
David females	–273.9	–134.0	+3.08	+0.26
Hereford males	– 92.6	+ 20.6	+0.001	–0.09
Hereford females	–239.7	– 76.3	+4.73	+0.07
Angus males	–231.0	– 28.6	–0.09	+0.37
Angus females	–540.6	+103.4	+1.43	–0.01
All males	–134.4	+ 13.8	–0.64	+0.53
All females	–382.0	– 67.9	+4.20	+0.07
All animals	–323.4	– 51.5	+2.23	+0.18

Angus females had the lowest average rates and efficiencies of gain. This is in general agreement with previous reports on this herd (Dahmen and Bogart, 1952; MacDonald *et al.* 1956; Williams, 1955). However, some variation appears to occur between lines in different years.

In a discussion of serum phosphatase levels, complications arise with respect to definitions of a standard unit of activity. The unit used in this paper was the Bodansky unit which is the number of mg. of inorganic phosphate per 100 ml. serum liberated from 0.5 percent sodium beta glycerol phosphate incubated at 37° for one hour. Another unit often used is the King and Armstrong unit which, as used by Gutman and Gutman, is defined in terms of the liberation of one mg. percent of phenol and is approximately double the value of the phosphate unit used here (Hawk, Oser, and Summerson, 1951). The method of Bessey, Lowry, and Brock as used by Kunkel *et al.* (1953) has as its unit the number of micromoles of p-nitrophenol liberated per liter of serum per hour at 38° from p-nitrophenyl phosphate. Each micromole per liter of serum per hour is equivalent to 1.79 Bodansky units per 100 ml. serum per hour.

The serum of normal human adults contains 5-10 King-Armstrong units (about 2.0 - 3.5 Bodansky units) of alkaline phosphatase per 100 ml. and 0.6 - 2.0 King-Armstrong units of acid phosphatase. Crookshank *et al.* (1952) record normal values of serum alkline phosphatase for beef cows and sheep on pasture. For samples taken during lactation, the levels in the beef cows appeared to be grouped in two ranges between 1.0 and 2.9 Bodansky units and between 13.0 and 24.9 units. The levels for sheep were 11.1 ± 0.3 Bodansky units per 100 ml. plasma. Kunkel *et al.* (1953) recorded average levels between 3.07 and 3.61 micromole units per liter (5.5 to 6.4 Bodansky units) of serum for European and Zebu-cross beef calves 8 to 14 months of age. Fletcher *et al.* (1956) obtained values from 4.39 to 8.16 micromole units per liter (8.0-14.7 Bodansky units) in Brahman calves from 8 to 11 months of age in a three-year study.

The levels recorded in the present study (2.7 to 9.6 Bodansky units) lie within the limits of those reported previously.

The mean serum inorganic phosphate level of 7.88 mg. per 100 ml. and a range of 4.2-9.7 mg. percent also appears to agree with data in the literature. Haag and Jones (1935) found plasma inorganic phosphate levels of 7.68 mg. percent for dairy calves 6 to 12 months of age in the Oregon district. The lactating beef cows studied by Crookshank *et al.* (1952) had a somewhat lower mean value of 5.4 mg. per 100 ml. serum. Using heifers and cows of the Shorthorn, Hereford, and Angus breeds, Long *et al.* (1952) recorded levels between 3.5 and 7.5 mg. per 100 ml. plasma.

Comparisons Between Sexes

Serum alkaline phosphatase levels were higher in all the male groups than in the females. While there is a significant difference between Angus males and Angus females and between all males and all females, many females had levels corresponding to some of the males. This indicates a considerable overlap in the ranges of the two sexes.

All male groups exhibited higher serum acid phosphatase levels than the female groups. These differences were significant in the case of the Hereford males and females and all males and females. While there was once again an overlap in the ranges of the values for males and females, this overlap was not great.

The blood inorganic phosphate levels were not sex dependent. A rather more variable pattern could be seen. David males had higher levels than David females while Angus males had significantly higher levels than the Angus females. In all other cases the females showed, on the average, higher blood inorganic phosphate levels than the corresponding males. This means that blood phosphate levels are less sex dependent than are rectal temperature (Williams *et al.*, 1953), heart rate (Williams *et al.*, 1954), rate of gain, feed economy, serum alkaline phosphatase, or serum acid phosphatase.

Serum inorganic phosphate, as would be expected, fairly closely paralleled the blood inorganic phosphate, the Angus males having higher serum and blood inorganic phosphate levels than the Angus females. All lines within the Herefords showed higher levels of both for the females than for the males. However, the overall male average was higher than that of the females.

Comparisons Between Breeds and Lines

Serum alkaline phosphatase levels for Hereford male and female calves were somewhat higher than those exhibited by the Angus males and females. Lionheart males had higher levels than Prince males, which in turn exhibited higher levels than the David males. The Prince females had higher levels than the David females.

Hereford male calves also had, on the average, higher acid phosphatase levels than Angus males. However, the Hereford females had a slightly lower level than the Angus females. Within the Hereford breed, the lines exhibited a trend similar to that shown for the alkaline phosphatase. Of the males, the Lionheart calves had the highest levels followed by the Prince and David. The Prince females had higher levels than the David.

Blood inorganic phosphate levels were lower in the Hereford males than in the Angus males and higher for the Hereford females than the Angus females. The David males showed the highest blood phosphate levels of the Hereford lines. The Lionheart males had higher levels than the Prince, while the Prince females had higher levels than the David.

The serum phosphate relationships paralleled the blood phosphate with a lesser degree of difference between the various groups.

Correlations and Regression Coefficients Between the Performance and Blood Constituent Data

Simple correlations between rate of gain, feed consumption per 100 pounds gain, and age at 800 pounds were significant. Simple correlations of nearly the same order were found for alkaline and acid phosphatase with these three performance characteristics. These high correlations suggest that either there were considerable sex differences producing the relationships or there was an actual correlation within breeds and sexes between blood phosphatases and the performance data.

In order to test these two points, correlations were determined at an intra-class level between feed consumption per unit gain, age at

800 pounds, alkaline and acid phosphatase, and rate of gain. There was a consistent relationship between the performance characteristics with one exception (Table 6). However, the blood constituents were not as consistent. Alkaline phosphatase was consistently positively correlated with rate of gain in the females, but there was a variable relationship in the males, both Prince and Angus males showing a negative correlation. Acid phosphatase showed considerable variation and it seems likely that the high correlation was produced by the sex differences.

The anomaly in the correlation between age at 800 pounds and rate of gain occurs in the Prince males where a positive correlation was recorded. It is a significant fact that the fastest gaining male calf was a Prince calf which was also the oldest male calf at 800 pounds having been retarded at weaning. This combination of factors contributed to the positive correlations between age at 800 pounds and rate of gain seen in the Prince, Hereford, and all males.

The regression coefficients provide further weight for the correlation coefficients especially with regard to the consistent relationship between alkaline phosphatase and rate of gain in female calves. The slopes of the regression lines for all groups of females are comparable, while those for the male groups indicate that alkaline phosphatase and rate of gain are quite independent. The acid phosphatase regression coefficients for the female groups show a lesser order of magnitude while those for the males indicate independent variation of acid phosphatase level and rate of gain.

Physiological Relationships Between the Data

There are a number of physiological implications to be derived from the data presented. Probably the most significant observation is the relationship in females of alkaline and acid phosphatases to rate of gain. The correlations are in accord with the suggestion by Moog (1946) that the bulk of the alkaline phosphatase is derived from osseous sources and that acid phosphatase is of liver and splenic origin. Bone growth would rather closely parallel body weight at this stage of growth so that it would be reasonable to expect a fairly close relationship between alkaline phosphatase and rate of gain. Similarly, acid phosphatase being of liver origin would be expected to be related to the rate of metabolic processes. More rapid growth would require an increased metabolic rate on the part of the animal and this would be reflected in an increased serum acid phosphatase.

There was no definite relationship between alkaline phosphatase and inorganic phosphate. In human rickets, it has been observed that the inorganic phosphate levels decrease while the alkaline phosphatase levels increase (West and Todd, 1956). However, the data in the present study indicate that there is no such relationship within the normal range of inorganic phosphate levels. This is in agreement with the findings of Crookshank *et al.* (1952).

The correlation between blood and serum inorganic phosphate provides some interesting information. Within the same animal, the haematocrit is the determining factor in this relationship. Since the average haematocrit was 45 percent (Price *et al.* 1957), the amount of phosphate carried in the red blood cells may be calculated. In 100 mg. of whole blood there would be $\frac{7.88 \times 55}{100}$ or 4.33 mg. of inorganic phosphate in the serum. There remains 0.88 mg. of inorganic phosphate present in the red blood cells. This presupposes that the inorganic phosphate content of serum is equivalent to that of plasma and that no more phosphate is retained in the fibrin of the clot than would be retained in the centrifuged cells alone. Thus the concentration of inorganic phosphate of red blood cells is only 11 percent of that in blood serum.

Summary and Conclusions

1. Rate of gain, feed economy, age at 800 pounds, serum alkaline phosphatase, serum acid phosphatase, and blood serum inorganic phosphates were considered for 44 calves at 800 pounds body weight.

2. A marked sex difference in rate of gain within both breeds and within the Hereford lines was observed. The average rate of gain for the male calves exceeded that of the female calves by 0.70 pounds per day.

3. The males made more economical gains than the females. Within the Hereford males, the Prince males were more economical than either the Lionheart or the David males. The Hereford males in general were also more economical than the Angus males. Similarly, the Hereford females ate less feed per unit of gain than the Angus.

4. Within breeds and also within the Hereford lines, the females were significantly older than corresponding males at 800 pounds body weight.

5. Serum alkaline phosphatase levels in Angus males were significantly higher than those in Angus females. In general, levels for male calves were higher than levels for female calves.

6. Serum acid phosphatase levels showed significant differences between sexes, all males averaging higher levels than all females. Hereford males had significantly higher levels than Hereford females.

7. Blood and serum inorganic phosphate levels varied from animal to animal in a manner which was unrelated to sex, significant sex differences being observed in only the Angus calves. In this case the males had higher levels than the females.

8. Rate of gain was significantly and negatively related to feed economy and age at 800 pounds body weight. It was also positively related to serum alkaline phosphatase and serum acid phosphatase levels.

9. Serum alkaline phosphatase levels were positively correlated with serum acid phosphatase.

10. Blood inorganic phosphate was positively related to serum inorganic phosphate.

11. Female calves showed a consistent correlation in all lines between alkaline phosphatase and rate of gain. A somewhat less consistent correlation was observed in females between acid phosphatase and rate of gain.

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