

Rate and Efficiency of Gains in Beef Cattle

*IV. Blood Hemoglobin, Glucose, Urea,
Amino Acid Nitrogen, Creatinine, and
Uric Acid of Growing Hereford
and Angus Calves*

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Introduction

With the development of improved methods for analysis of blood, a valuable tool has been placed in the hands of experimenters in animal physiology, nutrition, and genetics. Isolated hematological studies carried out during the past 30 years have advanced biology in many ways, and have permitted explanation of many metabolic interrelationships. Bell and Irwin (1938) state that if a more accurate measurement of the variation of blood constituents in normal animals were available, it might be used as a yardstick with which to compare fluctuations in the blood characters in various diseases. Ferguson, Irwin, and Beach (1945) indicate that a study of blood is undoubtedly of even greater importance in veterinary than in human practice, for the veterinarian, since he cannot communicate with his patients, is necessarily restricted to the use of objective symptoms. Knowledge of normal blood composition is obviously a preliminary necessity for the interpretation of results in studies employing cattle as experimental animals, or as an aid in veterinary diagnostics.

So far, no extensive work on the chemical constituents of the blood of domestic animals, particularly of beef cattle (Albritton, 1952) has been published. Many workers are forced to use results obtained by early investigators who employed beef blood, available in abattoirs, as a medium for evaluating a chemical analytical method or technique. Other workers use data on chemical constituents of blood of mature dairy cows in the absence of data on beef cattle. The work of Turner and Herman (1931) would suggest that the assumption by investigators that the chemical composition of blood of mature dairy cows and growing beef cattle is the same, or similar, is indeed hazardous. To extend the use of blood analysis to beef cattle, normal values must be established for the various chemical constituents.

In the course of study at Oregon State College (MacDonald and associates, 1953, 1954) considerable data on growing beef animals under various conditions have been accumulated. Data from

chemical analyses of venous blood samples drawn from Hereford and Aberdeen Angus bull and heifer calves of approximately 500 and 800 pounds body weight will be presented. They are offered as basic biochemical data essential in the interpretation of bovine physiology.

Review of Literature

Of published data on the chemical composition of bovine blood, many analyses are from dairy cattle, some are from cattle of unreported breeding, and relatively few are from beef cattle.

In general, most studies of blood *hemoglobin* agree with the value of 12.0 g. per 100 ml. listed by Dukes (1943). Braun (1946) found that young dairy cattle showed a slightly higher average hemoglobin level (12.2 g. per 100 ml.) than did older cattle (11.8 g. per 100 ml.). Byers, Jones, and Haag (1952) reported an average of 10.6 g. per 100 ml. for Holstein and 11.3 g. per 100 ml. for Jersey cattle. The range for 146 Holsteins was 8.0 to 13.5 g. per 100 ml. and for 288 Jerseys from 7.5 to 14.5 g. per 100 ml.

Literature relating to bovine *blood sugar* levels shows that there is no single representative average. Workers using dairy cattle have reported wide variations in values depending on physiological state. Thus Hewitt (1930) reported values of 79 to 95 mg. per 100 ml. of blood for dry cows and 50 to 63 mg. per 100 ml. for lactating cows. He also quoted average values ranging from 41 to 120 mg. per 100 ml. based on the work of a number of other investigators. Hodgson, Riddell, and Hughes (1932) obtained average values of 100.4 mg. per 100 ml. for dairy cattle 1 to 6 days old, and a progressive decrease with age for 2 years to a mean of 55.0 mg. per 100 ml. No significant differences in blood sugar were found between Ayrshire, Guernsey, Holstein, and Jersey cattle. In four cows the average blood sugar of 58.5 mg. per 100 ml. increased to 65.9 mg. per 100 ml. on samples determined before and after the cows were brought into the barn. Hodgson, Riddell, and Hughes obtained their blood samples from the ear. Dukes (1943) quoted a range from 40 to 60 mg. per 100 ml. for dairy cattle.

Folin and Denis (1914), on analyzing mixed beef blood at time of slaughter, reported *urea* nitrogen values averaging 14.0 mg. per 100 ml. of blood. Scheunert and von Pelchrzim (1923) reported ranges from 10.0 to 23.7 mg. per 100 ml. Fearon (1926) gave a blood urea nitrogen range from 13.6 to 15.3 mg. per 100 ml. More recently, Colby and associates (1950) reported average blood urea nitrogen values of 12.0 mg. per 100 ml., and Dinning and associates

(1948) noted that the blood urea nitrogen level of one steer fed urea rose to 30 mg., while the group average rose from 14 to 24 mg. per 100 ml.

From a review by Hayden of the composition of cattle blood (mainly dairy), Dukes (1943) listed 4.0 to 8.5 mg. per 100 ml. as the range for *amino acid nitrogen*. The lack of additional literature (Albritton, 1952) on amino acid nitrogen in cattle blood is surprising.

Blood concentrations of *creatinine* have been reported by several investigators, Folin and Denis (1914) reported an average creatinine value of 2 mg. per 100 ml. of whole blood. Hayden and coworkers (1920, 1924, 1928) reported averages of 1.20, 1.37, and 1.84 mg. per 100 ml., while Scheunert and von Pelchrzim (1923) gave creatinine ranges from 1.2 to 2.5 mg. per 100 ml. of cattle blood. Anderson, Gayley, and Pratt (1930) obtained an average of 1.42 mg. per 100 ml. from dairy cattle blood with values ranging from 1.11 to 1.94 mg., and Dukes (1943) reported a normal blood creatinine range for cattle from 1.0 to 2.07 mg. per 100 ml. of whole blood. Recently, Colby and his associates (1950) reported a creatinine average value of 1.32 mg. per 100 ml. for beef cattle whole blood.

Folin and Denis (1914) reported a *uric acid* value of 0.2 mg. per 100 ml. for mixed cattle blood at time of slaughter. Later, using improved methods, Benedict (1915) found a uric acid content of 2.0 mg. per 100 ml. of blood. Hayden and Tubanguí (1920) obtained an average uric acid content of 2.12 with a range from 1.60 to 2.64 mg., Hayden and Sholl (1924) obtained an average of 2.08 mg., and Hayden and Fish (1928) reported an average of 2.04 mg. per 100 ml., in studies involving dairy cattle. Scheunert and von Pelchrzim (1923) found a uric acid range from 1.0 to 4.2 mg. per 100 ml., and Anderson, Gayley, and Pratt (1930) found an average of 2.08 mg. and values ranging from 1.50 to 3.22 mg. per 100 ml. of blood.

Methods

Data presented in this paper were obtained from 45 beef calves housed at the Oregon State College Beef Barn. The group was composed of purebred Hereford and Aberdeen Angus bulls and heifers. Management procedures used and recommended previously at this station (Dahmen and Bogart, 1952; MacDonald, 1954) were adopted for the present study. One-inch pellets composed of two parts half-ground alfalfa and one part concentrate comprised the entire ration (Nelms, Williams, and Bogart, 1953). Animals were fed individually

twice daily. Feed was available in the morning from 6:30 to 9:30 and in the afternoon from 3:30 to 6:30. Quantity of feed was such that there was some weighback daily, and thus *ad libitum* feeding was simulated. Quantities of food consumed daily varied from animal to animal, but each ate food regularly every day, with only minor daily variations, except for a gradually increasing intake. Relationship between blood chemistry, rate of gain, and feed intake will be covered in a later paper. Calves had access to water at all times through automatic drinking cups. Pens, in which wood shavings were used for bedding, housed the calves in monosexual groups of six.

Short of starvation, it would be very difficult to place a ruminant animal in a post-absorptive state. In order to standardize the possible effects of diurnal rhythms and excitation, each animal was bled at the manger prior to the morning feeding. Fifteen ml. samples were drawn from the right jugular vein at body weights of approximately 500 and 800 pounds.

Methods used to determine concentrations of the blood constituents were those developed and extensively employed in other studies, and which have been summarized by Hawk, Oser, and Summerson (1951).

For the determination of hemoglobin, oxalated blood was treated with saponin (Oldfield, 1952) and the color density read in a Spencer hemoglobinometer. Oxalated whole blood was employed for glucose determinations by the Somogyi-Shaffer-Hartmann method (Somogyi, 1926). Deproteinization was accomplished by laking 1 volume of blood with 7 volumes of water; after adding 1 volume of a 10 per cent solution of $ZnSO_4 \cdot 7H_2O$ and mixing, 1 volume of 0.5N NaOH was added with continuous shaking. After a few minutes the solution was filtered through a dry filter paper. Aliquots of the filtrates were heated with the copper reagent and titrated with thiosulfate. Values were determined by comparison against a standard. For other blood constituents Haden's modification of the Folin and Wu preparation of protein-free filtrate was used (Hawk, Oser, and Summerson, 1951).

Urea was determined according to Looney's (1930) modification of the procedure of Karr (1924). Uric acid content was determined according to a method by Brown (1945). The amino acid determination was based on an original proposal by Folin with improvements by Danielson (1933) and Sahyun (1939), and methods of adaptation for photometric measurement by Frame, Russell, and Wilhelmi (1943) and Russell (1944). The Folin and Wu method for creatinine, based on the Jaffe reaction, was employed using a creatinine standard prepared according to Hawk, Oser, and Summerson

(1951). The picric acid used in both the creatinine and creatine determinations was prepared according to Peters (1942).

Creatinine nitrogen can be computed by multiplying the creatinine values (Tables 1 through 4) by the factor 0.372. *Urea* can be computed by multiplying urea nitrogen values by the factor 2.143. *Uric acid nitrogen* can be computed by multiplying the uric acid values by the factor 0.333.

Data on Blood Constituents

Data on blood constituents obtained from Hereford males are given in Table 1, from Hereford females in Table 2, from Angus males in Table 3, and from Angus Females in Table 4. The code numbers are those of the animals in the Oregon series, and will be used again in succeeding papers. The blood concentrations were determined from jugular vein samples drawn when the animals weighed 500 pounds; and again when the cattle weighed 800 pounds. Data from individual animals are presented so that information may be available in the literature for precise calculation of interrelations between the variables studied. Comparable data on urine will be given in a subsequent manuscript in this series.

Hemoglobin

Data on blood hemoglobin (Tables 1 to 4) have been summarized in Table 5 and plotted in Figure 1. The average value at 500 pounds body weight is the same as the figure of 12.0 g. per 100 ml. given by Dukes (1943), and the value of 12.3 g. per 100 ml. at 800 pounds is only slightly higher. In beef cattle there is a slight increase in hemoglobin with age, while hemoglobin decreases with age in dairy cattle (Hodgson, Riddell, and Hughes, 1932).

There was considerable variation in hemoglobin between sex and breed groups and between individuals within sex and breed groups. Hemoglobin values ranged from 10.3 to 14.1 g. per 100 ml. Variability was greatest in the Herefords. The Hereford females exhibited the widest range of blood hemoglobin values at both 500 pounds and 800 pounds body weight. The blood hemoglobin values for Hereford males ranged fairly widely at 800 pounds body weight, and somewhat less at 500 pounds. Individual variation among the Angus females and Hereford males may be said to be similar, and in both was much greater than among Angus males. Except for Hereford females, variability was greater at 800 pounds than at 500 pounds body weight. On the other hand, the variability in hemoglobin values was much less in this series of data on beef cattle than the variability reported for

TABLE 1. BLOOD HEMOGLOBIN, GLUCOSE, UREA, AMINO ACID NITROGEN, CREATININE, AND URIC ACID CONCENTRATIONS IN HEREFORD MALE CATTLE AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Animal code number	Hemoglobin		Glucose		Urea		Amino acid nitrogen		Creatinine		Uric acid	
	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight
	<i>Per cent</i>	<i>Per cent</i>	<i>mg./100 ml.</i>									
3	11.3	*	77	*	13	*	7.2	*	0.9	*	2.2	*
4	12.5	12.6	58	70	17	20	8.0	6.8	1.6	0.8	2.2	2.2
8	11.5	12.3	47	63	10	13	6.9	6.6	1.5	0.6	2.2	2.2
10	11.1	12.1	56	53	23	16	6.7	7.3	1.6	1.6	1.3	1.0
12	12.1	13.4	51	72	12	18	7.8	7.2	1.4	2.3	1.9	2.1
13	12.3	11.4	71	61	17	11	7.1	5.8	1.4	2.1	2.1	1.8
16	12.2	13.0	49	49	18	14	7.6	7.1	1.6	2.5	1.7	2.0
18	12.0	12.0	49	56	28	17	5.5	5.3	2.7	2.6	2.5	1.5
20	11.8	12.9	56	61	15	11	5.4	6.8	1.2	0.9	1.7	1.7
21	12.0	12.6	56	61	12	10	6.7	6.7	1.5	0.9	2.3	1.8
22	12.1	11.3	58	89	11	15	6.0	6.2	1.4	2.1	2.1	1.7
26	11.5	10.5	44	63	14	11	6.3	6.8	1.4	1.5	1.5	1.3
28	10.5	11.2	58	84	19	18	7.1	6.9	2.2	1.1	1.8	2.2

* Hereford male No. 3 died of bloat five days after blood sampling.

TABLE 2. BLOOD HEMOGLOBIN, GLUCOSE, UREA, AMINO ACID NITROGEN, CREATININE, AND URIC ACID CONCENTRATIONS IN HEREFORD FEMALE CATTLE AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Animal code number	Hemoglobin		Glucose		Urea		Amino acid nitrogen		Creatinine		Uric acid	
	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight
	<i>Per cent</i>	<i>Per cent</i>	<i>mg./100 ml.</i>									
1	12.5	12.5	49	56	20	11	4.8	7.9	2.3	2.4	2.3	1.4
2	11.4	13.3	61	92	29	14	6.7	6.2	1.7	0.9	1.6	2.1
5	12.0	12.3	46	77	12	16	7.8	7.4	1.2	1.9	1.5	1.2
6	12.3	12.1	41	61	14	13	8.1	7.6	1.7	1.8	1.7	1.4
7	10.3	11.3	53	70	17	18	6.7	8.4	1.4	1.4	1.2	1.5
9	11.5	11.0	51	63	26	16	6.7	7.3	1.5	1.8	1.9	2.2
11	11.6	14.3	75	77	11	16	6.7	7.4	1.4	2.1	1.9	1.8
15	12.3	13.6	68	61	09	17	6.5	7.6	1.4	1.2	2.0	1.3
17	12.5	13.3	58	58	13	11	7.9	6.8	1.5	1.1	1.9	1.9
19	11.5	11.6	51	65	09	17	6.1	8.0	1.3	1.2	2.0	1.9
23	11.5	*	63	*	28	*	7.4	*	1.0	*	1.6	0.0
25	14.1	10.6	53	82	23	14	6.9	7.8	1.5	1.7	2.5	2.3
27	13.2	12.2	63	70	15	17	6.4	6.3	1.5	1.8	1.6	1.8
29	10.3	11.2	92	70	16	18	6.2	7.3	1.4	1.9	1.3	1.1
32	11.1	12.2	68	61	22	23	6.6	8.5	1.5	1.8	1.3	2.4

* Hereford female No. 23 was culled after 99 days in the test because of stiffness in rear quarters. Autopsy showed only excess fat deposition.

TABLE 3. BLOOD HEMOGLOBIN, GLUCOSE, UREA, AMINO ACID NITROGEN, CREATININE, AND URIC ACID CONCENTRATIONS IN ANGUS MALE CATTLE AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Animal code number	Hemoglobin		Glucose		Urea		Amino acid nitrogen		Creatinine		Uric acid	
	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight
	<i>Per cent</i>	<i>Per cent</i>	<i>mg./100 ml.</i>									
51	12.0	12.5	53	63	15	12	4.1	7.0	2.5	1.1	2.6	1.9
55	12.5	12.3	65	46	14	09	7.2	7.1	1.4	0.7	2.2	1.7
56	12.4	13.2	46	77	16	17	6.6	7.3	1.7	1.2	2.5	2.5
57	12.1	11.5	60	68	16	10	7.0	5.8	1.0	0.8	1.9	1.6
60	12.2	12.6	77	70	09	20	7.0	8.3	1.1	0.9	2.5	2.7
63	11.0	12.2	63	75	20	16	7.7	7.2	2.3	1.2	2.3	2.6

TABLE 4. BLOOD HEMOGLOBIN, GLUCOSE, UREA, AMINO ACID NITROGEN, CREATININE, AND URIC ACID CONCENTRATIONS IN ANGUS FEMALE CATTLE AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Animal code number	Hemoglobin		Glucose		Urea		Amino acid nitrogen		Creatinine		Uric acid	
	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight	At 500 lbs. body weight	At 800 lbs. body weight
	<i>Per cent</i>	<i>Per cent</i>	<i>mg./100 ml.</i>									
50	13.2	13.8	48	72	15	16	7.9	7.5	1.9	1.2	1.9	2.3
52	12.4	11.2	56	56	29	16	8.8	7.6	1.0	1.2	2.6	3.1
53	11.0	11.3	63	63	27	16	8.2	8.2	1.5	1.4	2.3	2.4
58	13.1	13.6	46	92	19	16	7.3	8.7	1.7	1.9	3.4	2.9
59	12.4	13.3	61	65	16	24	8.4	8.1	1.3	0.4	2.1	1.9
61	12.0	12.5	65	61	23	09	8.0	7.4	2.1	1.2	2.2	2.5
64	11.5	12.4	58	65	24	14	7.8	7.9	2.7	0.6	3.4	3.3
65	13.0	13.0	51	51	29	19	7.6	8.4	2.3	1.1	2.7	4.1
66	13.5	12.6	77	56	07	18	6.5	7.8	2.4	0.6	1.5	1.4
68	12.0	*	53	*	17	*	7.5	*	0.8	*	2.0	0.0
69	11.9	12.7	53	58	28	18	7.7	7.5	1.0	0.6	1.3	1.3

* Angus female No. 68 was born late in year (April 1, 1953), had not attained 800 lbs. weight after 131 days on the test, so testing was discontinued July 15, 1953.

TABLE 5. COMPARISON OF BLOOD HEMOGLOBIN CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood hemoglobin concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Increase (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	<i>g./100 ml.</i>	<i>g./100 ml.</i>	<i>g./100 ml.</i>		<i>g./100 ml.</i>	<i>g./100 ml.</i>	<i>g./100 ml.</i>	<i>g./100 ml.</i>	
Hereford males	13	11.7	12.5	10.5	12	12.1	13.4	10.5	0.4
Hereford females	15	11.9	14.1	10.3	14	12.3	14.3	10.6	0.4
Angus males	6	12.0	12.5	11.0	6	12.4	13.2	11.5	0.4
Angus females	11	12.4	13.5	11.0	10	12.7	13.8	11.2	0.3
All males	19	11.8	12.5	10.5	18	12.2	13.4	10.5	0.4
All females	26	12.1	14.1	10.3	24	12.4	14.3	10.6	0.3
All Herefords	28	11.8	14.1	10.3	26	12.2	14.3	10.5	0.4
All Angus	17	12.2	13.5	11.0	16	12.6	13.8	11.2	0.4
All animals	45	12.0	14.1	10.3	42	12.3	14.3	10.5	0.3

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TABLE 6. COMPARISON OF BLOOD GLUCOSE CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood glucose concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Increase (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>		<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	
Hereford males	13	56	77	44	12	65	72	49	9
Hereford females	15	59	92	41	14	69	92	56	10
Angus males	6	61	77	46	6	67	77	46	6
Angus females	11	52	77	46	10	64	92	51	12
All males	19	58	77	44	18	64	89	46	6
All females	26	59	92	41	24	67	92	51	8
All Herefords	28	58	92	41	26	67	92	49	9
All Angus	17	58	77	46	16	65	92	46	7
All animals	45	58	92	41	42	66	92	46	8

other species. Albritton (1952) gives 14.0 to 18.0 g. per 100 ml. as the range in human males and 11.5 to 16.0 for human females. Range for the pig and for the rhesus monkey is given as 10 to 16 g. per 100 ml. Hemoglobin values for cattle are generally lower than for man.

Blood hemoglobin on the average was higher in females than in males, and this was especially true in the Angus. Average blood hemoglobin was higher in the Angus than in the Herefords for both males and females.

Blood hemoglobin averages for Hereford and Angus males and females were higher at 800 pounds body weight than at 500 pounds. Between 500 pounds and 800 pounds body weight, blood hemoglobin increased in 28 out of 42 of the cattle studied; blood hemoglobin decreased in 11 of the 42 and did not change in 3. Of the 11 decreases, 6 occurred from values above average at 500 pounds and 5 from average values or lower.

The lower range of hemoglobin values was similar for given groups at 500 pounds and at 800 pounds, and was not altered markedly (see Figure 1) by the general upward trend. The upper range, however, was definitely higher (an upper value of 12.5 g. at 500 pounds body weight as compared with 13.4 g. per 100 ml. at 800 pounds body weight) in the hemoglobin data collected at the higher body weight from Hereford males.

Blood glucose

Data on blood glucose from Tables 1 to 4 have been summarized in Table 6 and plotted in Figure 2. They were characterized by some variability both at 500 pounds body weight and at 800 pounds body weight. Hereford females at 500 pounds exhibited the greatest variability, but the variability was somewhat reduced at 800 pounds. The range of 41 to 92 mg. per 100 ml. may be considered similar to the range of 61 to 130 mg. per 100 ml. given by Albritton (1952) for man, and is much less than the range 82 to 266 mg. per 100 ml. given for the mouse. The average figure of 62 mg. per 100 ml. for venous blood glucose is much lower than the average value of 86 mg. per 100 ml. given by Albritton (1952) for venous blood glucose in man.

Hereford females had a slightly higher average blood sugar level than did Hereford males, while Angus males had higher blood sugar levels than did Angus females. This opposing interaction between sex and breed can lead to the spurious interpretation that at 500 pounds body weight there are no significant differences between *all males* and *all females* or between *all Angus* and *all Herefords*. There are blood glucose differences between males and females and between Hereford and Angus, but they are complex.

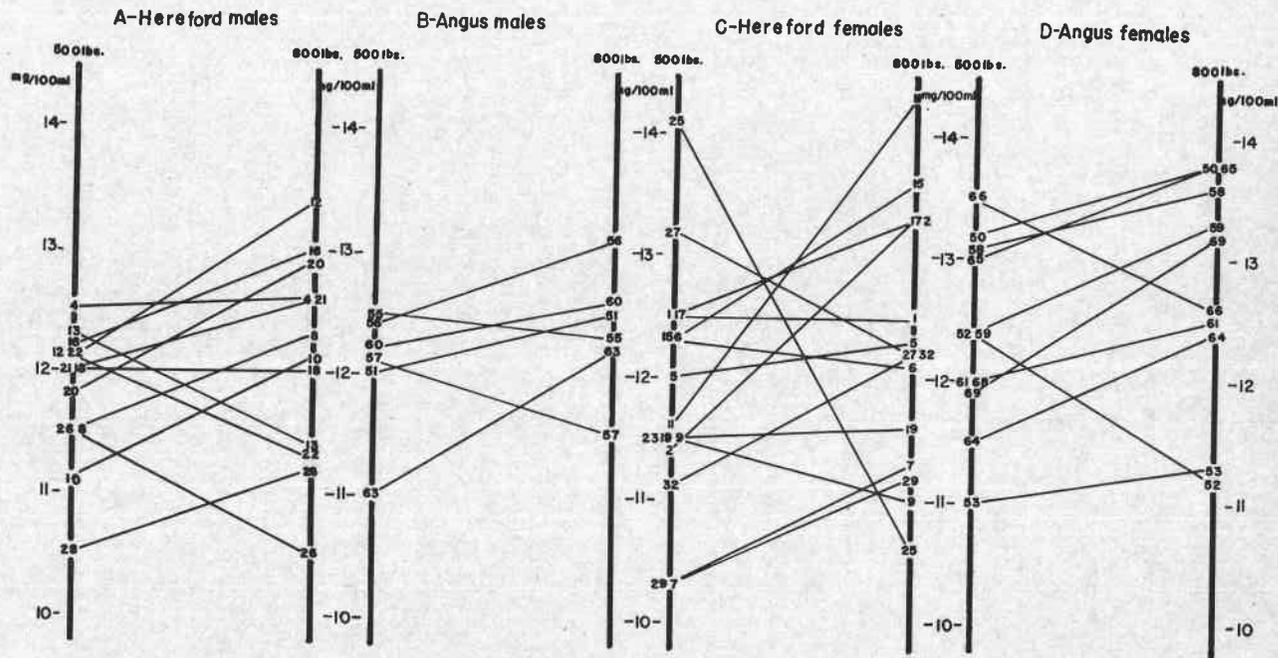


Figure 1. Blood hemoglobin for individual calves at 500 pounds body weight is plotted on the left ordinate of each graph, and the blood hemoglobin at 800 pounds body weight on the right. Hemoglobin concentrations in grams per 100 ml. are indicated to the left of the ordinates at 500 pounds, and on both the ordinate at 500 pounds and the ordinate at 800 pounds the hemoglobin levels for each calf are indicated by the code number of the calf. The code numbers of a given calf at 500 and

800 pounds body weight are connected by straight lines to show the average trend. A linear relationship between the level of blood hemoglobin and weight or time is not implied. Many more hemoglobin determinations would be required to show the temporal changes as body weight increased. The data on hemoglobin for Hereford males are given in A, for Angus males in B, for Hereford females in C, and for Angus females in D.

Between 500 pounds and 800 pounds body weight blood glucose increased from 58 to 66 mg. per ml. There was an increase in 28 out of 42 cattle studied, a decrease in 9, and no alteration in 5. Of the 9 decreases, 7 occurred from unusually high values at 500 pounds (see Figure 2). On the average, there was a statistically significant rise in blood glucose concentration, in all categories of cattle listed, with the increase in body weight from 500 to 800 pounds. The increase in glucose concentrations was 9 mg. and 10 mg. per 100 ml. for the Hereford males and females, and 6 mg. and 12 mg. per 100 ml. for Angus males and females.

Blood urea nitrogen

Blood urea nitrogen (Tables 1 to 4 and 7, Figure 3) usually fell within the normal range of 6 to 27 mg. per 100 ml. presented by Dukes (1943), although the values for several heifers and one bull slightly exceeded the upper limit of this range at 500 pounds body weight (Tables 1, 2, and 4). Blood urea nitrogen levels for beef cattle from 6.7 to 29.4 mg. per 100 ml. are low when compared with levels of 26 to 46 mg. per 100 ml. in human males and 11 to 29 mg. per 100 ml. in human females (Albritton, 1952).

At both 500 and 800 pounds, average blood urea level of males was lower than that of the females, and the Hereford group average was slightly lower than that of the Angus (Table 7). Blood urea averages decreased with the increase from 500 to 800 pounds body weight. It should be emphasized, however, that comparisons between *all Hereford* and *all Angus*, comparisons between *all males* and *all females*, and comparisons between 500-pound data and 800-pound data are biased by the exceedingly high average value of 21.5 mg. per 100 ml. for the Angus females at 500 pounds body weight. In the Angus females, the average blood urea dropped from 21.5 to 15.7 or a difference of 5.8 mg. per 100 ml., whereas the drops in Angus males, Hereford females, and Hereford males were 1.0, 1.6, and 1.8 mg. per 100 ml. respectively.

The range of values was wider in samples obtained at 500 pounds body weight than in those collected at 800 pounds body weight. Data from Angus males were less variable than those from Hereford males and females or Angus females (Figure 3). Angus males had low values of blood urea nitrogen with a range from 8.8 to 20.4 mg. per 100 ml. Except for one Hereford and two Angus females, this range held also for Hereford males and Angus females at 800 pounds body weight. At 500 pounds body weight, high levels of blood urea nitrogen were found sometimes in Hereford males and females, but were frequent in Angus females.

TABLE 7. COMPARISON OF BLOOD UREA NITROGEN CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood urea nitrogen concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Decrease (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>		<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	
Hereford males	13	16.1	28.0	10.2	12	14.5	20.0	10.0	1.6
Hereford females	15	17.6	29.4	8.8	14	15.8	23.3	11.3	1.8
Angus males	6	15.0	20.4	9.2	6	14.0	19.9	8.8	1.0
Angus females	11	21.5	29.4	6.7	10	15.7	24.2	9.3	5.8
All males	19	15.8	28.0	9.2	18	14.3	20.0	8.8	1.5
All females	26	19.0	29.4	6.7	24	15.8	24.2	9.3	3.2
All Herefords	28	16.9	29.4	8.8	26	15.2	23.3	10.0	1.7
All Angus	17	18.9	29.4	6.7	16	15.1	24.2	8.8	3.8
All animals	45	17.7	29.4	6.7	42	15.1	24.2	8.8	2.6

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TABLE 8. COMPARISON OF BLOOD AMINO ACID NITROGEN CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood amino acid nitrogen concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Increase (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>		<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	<i>mg./100 ml.</i>	
Hereford males	13	6.8	8.0	5.4	12	6.6	7.3	5.3	-0.2
Hereford females	15	6.8	8.1	4.8	14	7.5	8.5	6.2	+0.7
Angus males	6	6.6	7.7	4.1	6	7.1	8.3	5.8	+0.5
Angus females	11	7.8	8.8	6.5	10	7.9	8.7	7.4	+0.1
All males	19	6.7	8.0	4.1	18	6.8	8.3	5.3	+0.1
All females	26	7.4	8.8	4.8	24	7.6	8.7	6.2	+0.2
All Herefords	28	6.9	8.1	4.8	26	7.1	8.5	5.3	+0.2
All Angus	17	7.4	8.8	4.1	16	7.6	8.7	5.8	+0.2
All animals	45	7.1	8.8	4.1	42	7.3	8.7	5.3	+0.2

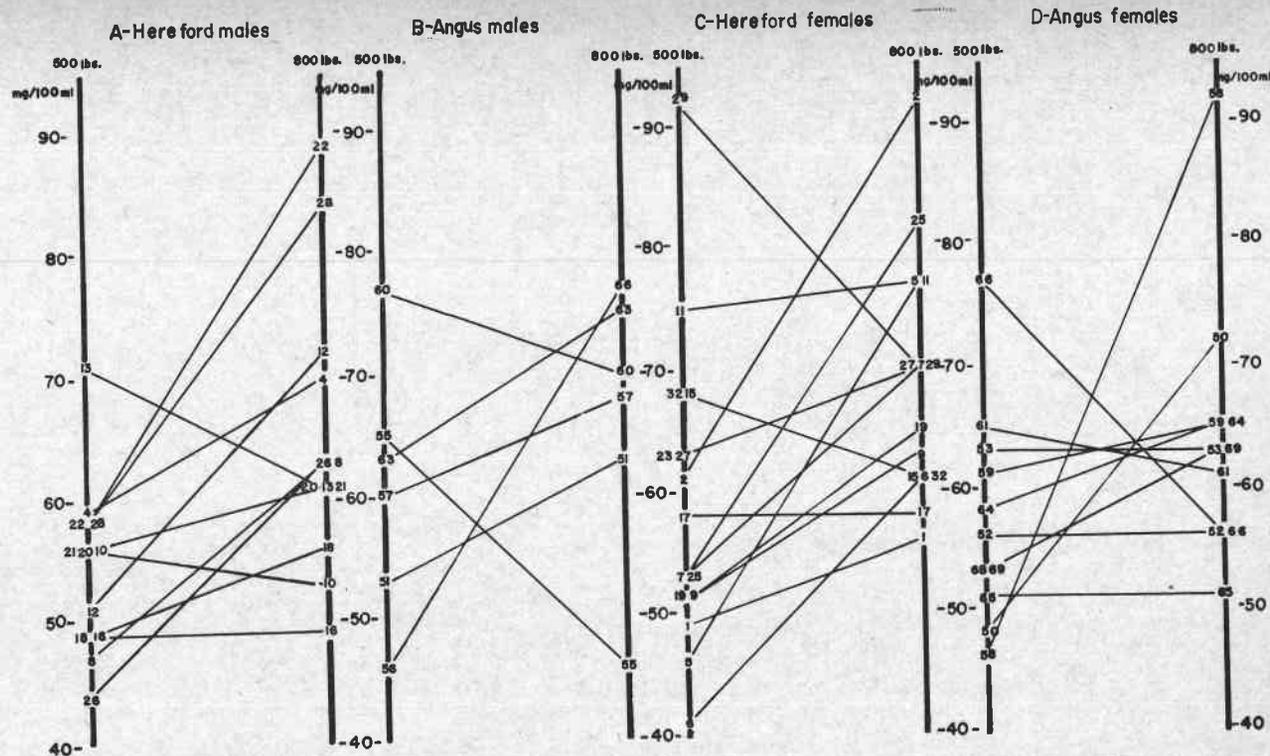


Figure 2. Blood glucose for individual calves at 500 pounds body weight is plotted on the left ordinate of each graph, and the blood glucose at 800 pounds body weight on the right. Glucose concentrations in mg. per 100 ml. are indicated to the left of the ordinates at 500 pounds, and on both the ordinate at 500 pounds and the ordinate at 800 pounds the glucose levels for each calf are indicated by the code number of the calf. The code numbers of a given calf at 500 and 800 pounds body weight are

connected by straight lines to show the average trend. A linear relationship of the level of blood glucose with weight or with time is not implied. Many more glucose determinations would be required to show the temporal changes as body weight increased. The data on glucose for Hereford males are given in A, for Angus males in B, for Hereford females in C, and for Angus females in D.

While over-all trend of the average is toward lower values of blood urea nitrogen at 800 pounds as compared with values at 500 pounds, of the 42 animals involved, decreases were recorded for only 25, while increases in urea nitrogen developed for 16. Even for the Angus females, which account for the greatest part of the average differences between 500 pounds, and 800 pounds, blood urea decreased in 7 and increased in 2 of the 10 animals available for study. While Hereford females showed an over-all drop of 1.8 mg. per 100 ml., decreases were obtained in only 6 and rises in 7 of the 14 heifers.

Amino acid nitrogen

Blood amino acid nitrogen averages (Table 8) for all the groups classified fell well within the normal range from 4.0 to 8.5 mg. per 100 ml., listed by Dukes (1943) for the cow, although one Angus heifer exceeded the upper limit at 500 pounds, while another exceeded it at 800 pounds body weight (Figure 4, Tables 1 to 4).

Variability (absolute magnitude of range of data) was similar for Hereford and Angus males and females at 500 pounds body weight and 800 pounds body weight (see Figure 4). At both 500 pounds and 800 pounds the average for *all males* was lower than that of *all females* (Table 8). At 500 pounds, the difference between males and females was marked for the Angus but nonexistent for the Hereford. Averages for Hereford males and females were lower than those for Angus males and females at 800 pounds; but at 500 pounds Hereford and Angus males had similar amino acid nitrogen levels in the blood, while Hereford females had lower levels than Angus females. Considerable variation within each group was apparent.

Average amino acid nitrogen concentration increased with the increase in body weight from 500 to 800 pounds in Hereford females and Angus males, while similar averages at both weights were obtained with Hereford males and Angus females. The clear-cut differences found for Hereford females and Angus males vanished when the data were combined as in *all females*, *all males*, *all Hereford*, *all Angus*, or *all animals*.

Of 12 Hereford males, 7 showed a drop in blood amino acid nitrogen between 500 pounds and 800 pounds body weight while 4 showed increases. Of 6 Angus males, 3 showed drops and 3 showed increases. The over-all increase in blood amino acid nitrogen for the Angus males from 500 pounds to 800 pounds body weight depended on the unusually low value of 4.1 mg. per 100 ml. for Angus bull B51 at 500 pounds body weight. Of the 14 Hereford females, 9 showed a drop in blood amino acid nitrogen and 5 showed an increase. Of 10 Angus females, 5 showed a drop and 4 an increase. Of all 42 beef cattle, 24 showed a drop and 16 showed an increase.

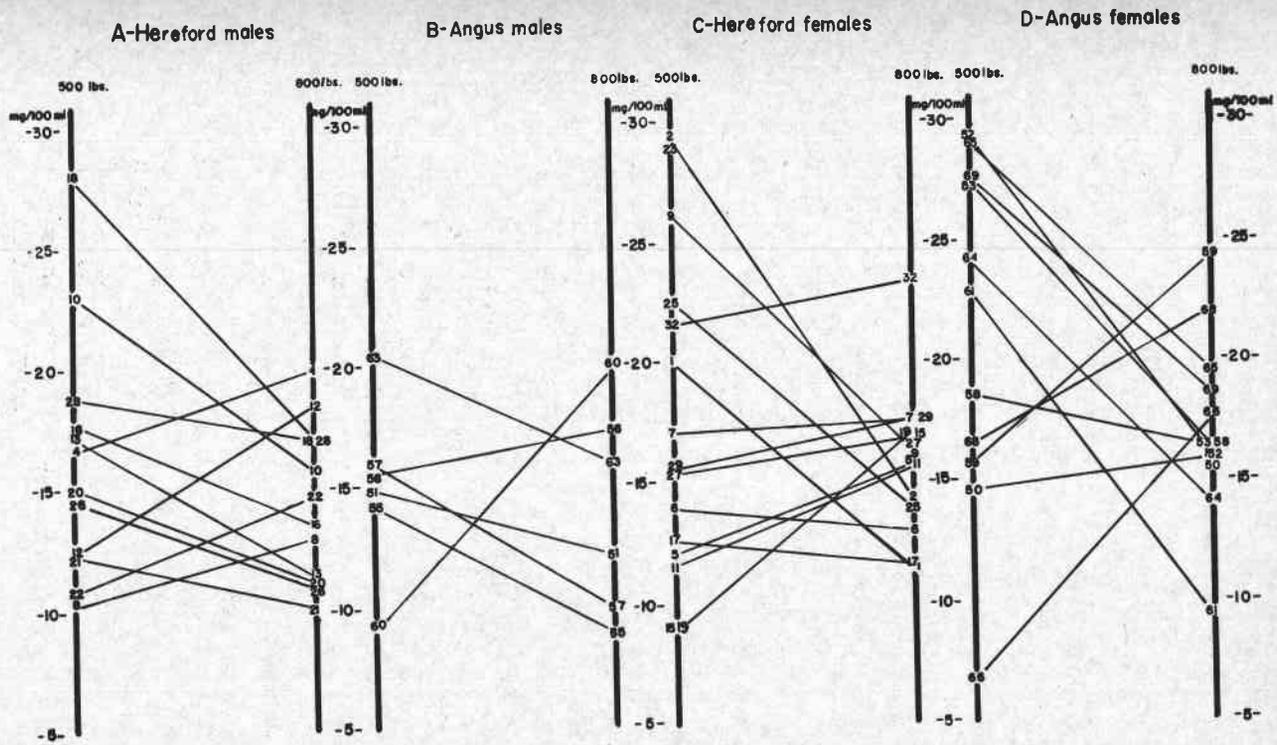


Figure 3. Blood urea nitrogen for individual calves at 500 pounds body weight is plotted on the left ordinate of each graph, and the blood urea nitrogen at 800 pounds body weight on the right. Urea nitrogen concentrations in mg. per 100 ml. are indicated to the left of the ordinates at 500 pounds, and on both the ordinate at 500 pounds and the ordinate at 800 pounds the urea nitrogen levels for each calf are indicated by the code number of the calf. The code numbers of a given calf at 500

and 800 pounds body weight are connected by straight lines to show the average trend. A linear relationship of the level of urea nitrogen with weight or with time is not implied. Many more urea nitrogen determinations would be required to show the temporal changes as body weight increased. The data on urea nitrogen for Hereford males are given in A, for Angus males in B, for Hereford females in C, and for Angus females in D.

TABLE 9. COMPARISON OF BLOOD CREATININE CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood creatinine concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Increase (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	mg./100 ml.	mg./100 ml.	mg./100 ml.		mg./100 ml.	mg./100 ml.	mg./100 ml.	mg./100 ml.	
Hereford males	13	1.57	2.7	0.9	12	1.58	2.6	0.6	+0.01
Hereford females	15	1.43	2.3	1.0	14	1.64	2.4	0.9	+0.21
Angus males	6	1.67	2.5	1.0	6	0.98	1.2	0.7	-0.69
Angus females	11	1.70	2.7	0.8	10	1.09	1.9	0.6	-0.61
All males	19	1.60	2.7	0.9	18	1.38	2.6	0.6	-0.22
All females	26	1.54	2.7	0.8	24	1.41	2.4	0.6	-0.13
All Herefords	28	1.49	2.7	0.9	26	1.62	2.6	0.6	+0.13
All Angus	17	1.69	2.7	0.8	16	1.05	1.9	0.6	-0.64
All animals	45	1.57	2.7	0.8	42	1.40	2.6	0.6	-0.17

TABLE 10. COMPARISON OF BLOOD URIC ACID CONCENTRATIONS IN HEREFORD AND ANGUS MALES AND FEMALES AT BODY WEIGHTS OF 500 POUNDS AND 800 POUNDS

Group	Blood uric acid concentrations								
	At 500 pounds body weight				At 800 pounds body weight				Increase (500 to 800 lbs.)
	Number of calves	Average	High	Low	Number of calves	Average	High	Low	
	mg./100 ml.	mg./100 ml.	mg./100 ml.		mg./100 ml.	mg./100 ml.	mg./100 ml.	mg./100 ml.	
Hereford males	13	1.96	2.3	1.3	12	1.79	2.2	1.0	-0.17
Hereford females	15	1.75	2.5	1.2	14	1.74	2.4	1.1	-0.01
Angus males	6	2.33	2.6	1.9	6	2.17	2.7	1.6	-0.16
Angus females	11	2.31	3.4	1.3	10	2.52	4.1	1.3	+0.21
All males	19	2.08	2.6	1.3	18	1.92	2.7	1.0	-0.16
All females	26	1.99	3.4	1.2	24	2.07	4.1	1.1	+0.10
All Herefords	28	1.85	2.5	1.2	26	1.76	2.4	1.0	-0.11
All Angus	17	2.32	3.4	1.3	16	2.39	4.1	1.3	+0.07
All animals	45	2.02	3.4	1.2	42	2.00	4.1	1.0	-0.02

Creatinine

The creatinine values, found in Tables 1 to 4 and 9, are consistent with those previously quoted for the literature (1.0 to 2.5 mg. per 100 ml.) except for 14 (16 per cent of 85 determinations) values lying below 1.0 mg. and 3 (4 per cent of 85 determinations) values at 2.6 or 2.7 mg. per 100 ml. (Figure 5). The range of creatinine values for beef cattle is somewhat greater than the range of 1.0 to 2.0 mg. per 100 ml. given by Albritton (1952) for man.

At 500 pounds body weight (Table 9, Figure 5) the greatest variability amongst individuals was found in Angus females, the least was found in Hereford females, while Hereford males and Angus males showed similar individual variability. At 800 pounds body weight the Hereford males showed the greatest individual variation and were followed by the Hereford females, the Angus females, and finally by the Angus males with the least variation (see Table 9 and Figure 5).

At 500 pounds body weight Angus females did not differ from Angus males, but Hereford females had a lower blood creatinine than did Hereford males. At 800 pounds body weight Angus females had a slightly, though not significantly, higher average creatinine value than did Angus males; and Hereford males and Hereford females had similar average levels of blood creatinine. The interaction between breed and sex tended to eliminate the difference between *all females* and *all males* at both 500 pounds and 800 pounds body weight.

At 500 pounds body weight Hereford and Angus males had similar (slightly higher in the Angus) average blood creatinines, but at 800 pounds body weight average for the Hereford males was very much higher than average for the Angus males. At 500 pounds body weight Hereford females had blood creatinine values significantly lower than Angus females, but at 800 pounds body weight Hereford females had a much higher average blood creatinine than did Angus females.

As Angus males at 500 pounds had a slightly higher blood creatinine average than did Hereford males, and since Angus females had a significantly higher average than Hereford females, the average for all Angus was significantly higher than the average for all Hereford. But at 800 pounds body weight, since Hereford males and Hereford females had respectively higher average creatinine levels than did Angus males and females, the all-Hereford average was much higher than the all-Angus average.

Hereford males had similar blood creatinine averages at 500 pounds and at 800 pounds body weight but the range of values, especially at the lower level, was much greater at 800 pounds body weight.

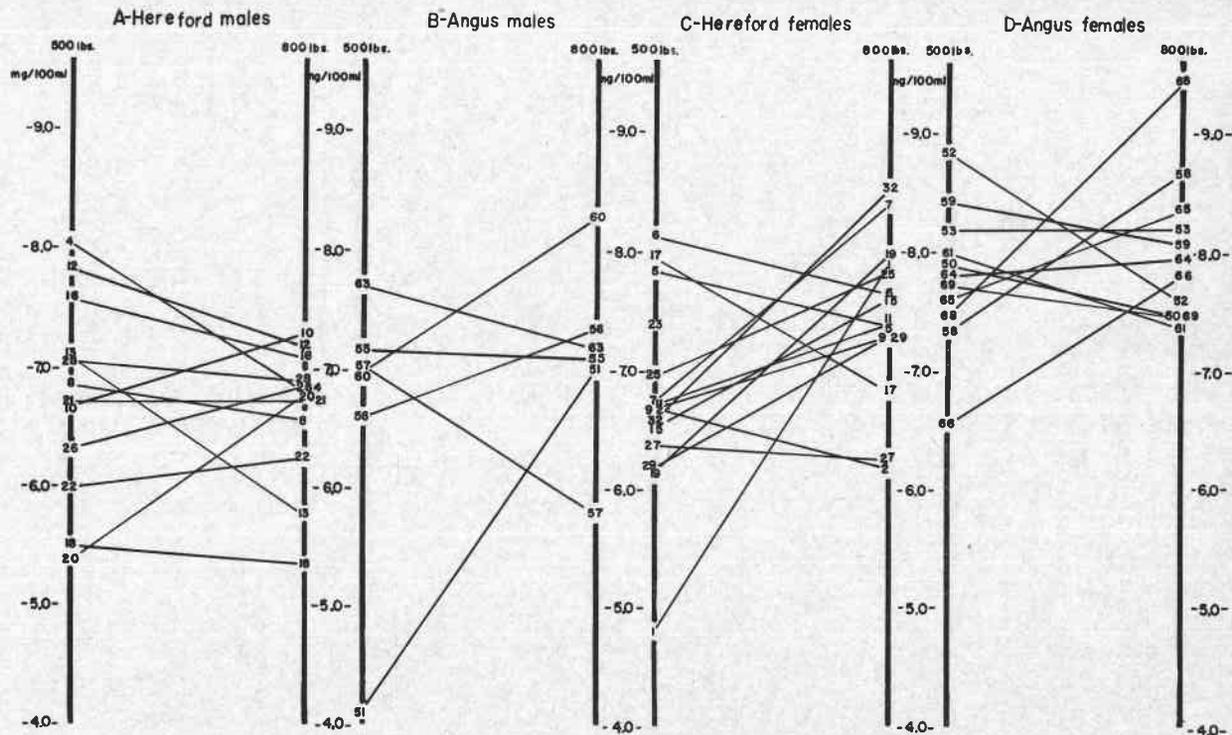


Figure 4. Blood amino acid nitrogen for individual calves at 500 pounds body weight is plotted on the left ordinate of each graph, and the amino acid nitrogen at 800 pounds body weight on the right. Amino acid nitrogen concentrations in mg. per 100 ml. are indicated to the left of the ordinates at 500 pounds, and on both the ordinate at 500 pounds and the ordinate at 800 pounds the amino acid nitrogen levels for each calf are indicated by the code number of that calf. The code

numbers of a given calf at 500 and 800 pounds body weight are connected by straight lines to show the average trend. A linear relationship of the level of amino acid nitrogen with weight or with time is not implied. Many more amino acid determinations would be required to show the temporal changes as body weight increased. The data on amino acid nitrogen for Hereford males are given in A, for Angus males in B, for Hereford females in C, and for Angus females in D.

Of the 12 animals studied, 5 showed very marked decreases in blood creatinine and 4 very marked increases; 1 showed a slight increase and 2 did not change.

Hereford females showed a significant increase in blood creatinine while growing from 500 to 800 pounds body weight. The range was slightly greater at 800 pounds body weight than at 500 pounds body weight. Of the 14 animals studied, 8 increased (2 markedly) and 5 decreased in respect to blood creatinine levels between 500 and 800 pounds body weight.

All 6 Angus males studied showed marked decreases in blood creatinine from 500 to 800 pounds body weight. The range for Angus males was less at 800 than at 500 pounds.

Angus females showed a significant drop in the blood creatinine concentration from 500 to 800 pounds body weight. The range was less at 800 pounds body weight. Of the 10 animals studied, 8 showed decreases (5 very marked) in blood creatinine and 2 showed a definite rise.

Over-all figures for male and female averages dropped between 500 and 800 pounds body weight. The all-Hereford figures showed a rise and the all-Angus a fall. Because of significant and opposing interaction between breeds and sex, the drop in average blood creatinine for all animals from 500 to 800 pounds body weight, although statistically significant, cannot be given a simple biological interpretation.

Uric acid

The uric acid values, found in Tables 1 to 4, and Table 10, are generally consistent on the low side with those of the literature previously quoted (1.0 to 2.5 mg. per 100 ml.), but Angus males had slightly higher values and Angus females markedly higher values than those previously reported (Figure 6). The range from 1.0 to 4.1 mg. per 100 ml. is greater than the range from 2.2 to 4.2 mg. per 100 ml. given by Albritton (1952) for man. The average value of 2 mg. per 100 ml. is significantly lower than the value of 3.2 mg. per 100 ml. given for man.

Individual variation was great among the Angus females at both 500 and 800 pounds body weight. Individual variation was less in the Hereford males and females than in Angus females, and was least among the Angus males.

At 500 pounds body weight, Hereford males had a slightly higher uric acid average than did Hereford females, but at 800 pounds body weight both had similar average levels of blood uric acid. Ranges for Hereford males and females were similar at both 500 pounds and 800 pounds body weight. At 500 pounds body weight,

Angus males and females had similar averages, but the range of values found in Angus females was much greater. At 800 pounds body weight, Angus females had a higher blood uric acid average than did Angus males. The range for Angus males was still restricted at 800 pounds body weight, but the upper range for females had been extended to 4.1 mg. per 100 ml.

Angus males had a higher average blood uric acid level than did Hereford males at both 500 pounds and 800 pounds body weight. Likewise, Angus females had generally higher blood uric acid levels than did Hereford females.

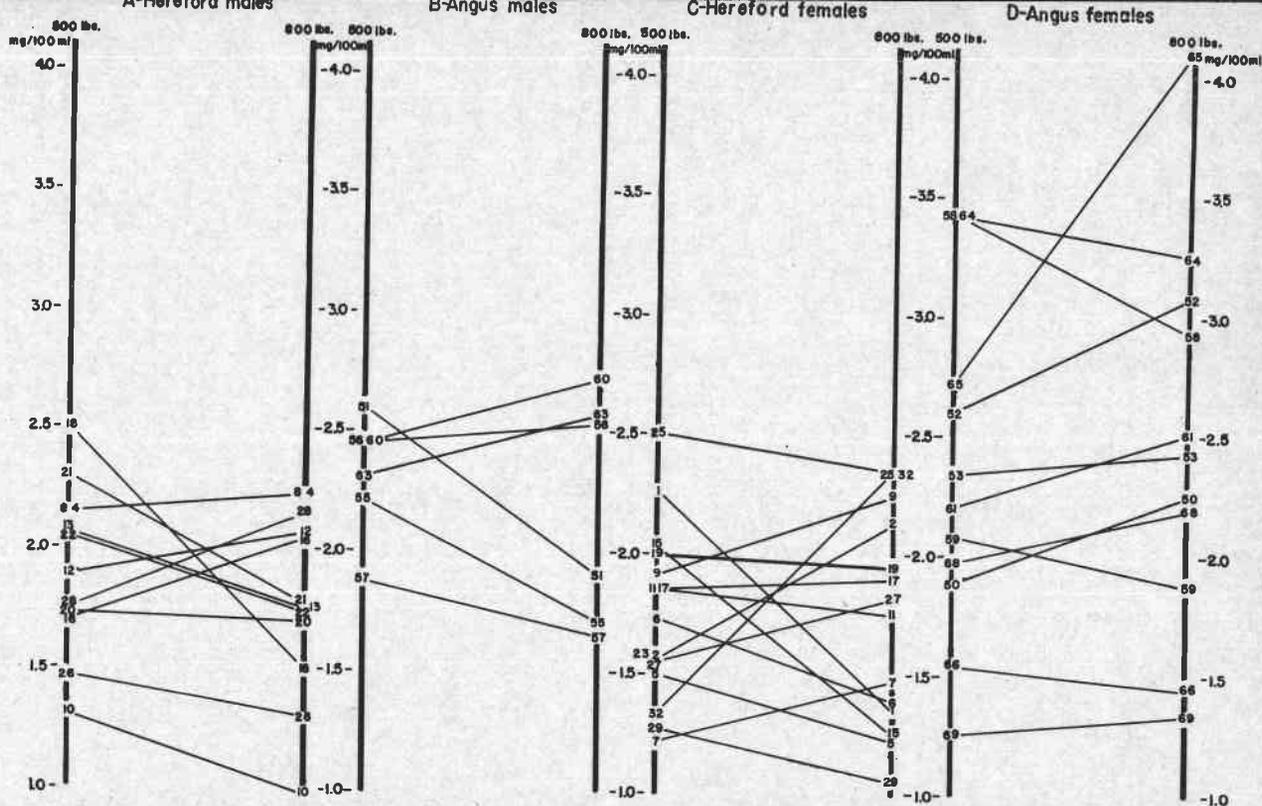
Between 500 and 800 pounds body weight, Angus males and Hereford males showed decreases in average blood uric acid, Hereford females were unchanged, and Angus females had increases. Thus, for *all males* there was a drop in uric acid from 500 pounds to 800 pounds body weight and for *all females* an increase. Due to opposing sex and breed interaction there were no marked differences from 500 pounds to 800 pounds body weight in average uric acid levels when the groups were combined as *all Herefords*, *all Angus*, or *all animals*.

Discussion

Data presented in Tables 1 to 10 require comparison with the literature and discussion from the standpoint of chemical similarities and differences between sexes, chemical similarities and differences between breeds, and of the physiology of growth.

Comparison with literature

Mention has been made of a few animals in which blood hemoglobin, glucose, urea nitrogen, amino acid nitrogen, creatinine, or uric acid concentration exceeded the normal range listed for the cow by Dukes (1943). Such values are not necessarily representative of abnormal animals or faulty laboratory technique. They more probably indicate that data on beef cattle may sometimes lie outside the range for dairy cattle, and that management procedures at Oregon State College during this study differed significantly from those used in the other studies quoted. Duke's range of the chemical constituents of whole blood of the cow was prepared by Dr. C. E. Hayden and is founded on Hayden's own work and that of other early investigators. The vast majority of data reported by Hayden were obtained from mature, lactating dairy cows by methods which have since been superseded. The present study involved young growing beef bull and heifer calves. All animals were in the same barn and had the same food over approximately 120 days (i.e., while gaining from 500 to 800 pounds



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Figure 6. Blood uric acid for individual calves at 500 pounds body weight is plotted on the left ordinate of each graph, and the blood uric acid at 800 pounds body weight on the right. Uric acid concentrations in mg. per 100 ml. are indicated to the left of the ordinates at 500 pounds, and on both the ordinate at 500 pounds and the ordinate at 800 pounds the uric acid levels for each calf are indicated by the code number of the calf. The code numbers of a given calf at 500 and 800 pounds body

weight are connected by straight lines to show the average trend. A linear relationship of the level of blood uric acid with weight or with time is not implied. Many more uric acid determinations would be required to show the temporal changes as body weight increased. The data on uric acid for Hereford males are given in A, for Angus males in B, for Hereford females in C, and for Angus females in D.

body weight). Seasonal and weather conditions were not identical at the time of collections from the different animals. Seasonal variation may account for some of the individual differences, but Hereford and Angus males and females have been considered as randomly distributed with regard to time of birth, and differences in the averages are reasonably representative of differences between the groups.

Blood hemoglobin, glucose, amino acid nitrogen, and urea can be considered as essentially in agreement with those in the literature. Blood urea values were often somewhat higher than those quoted in the literature review (10.0 to 23.7 mg. per 100 ml.) and occasionally somewhat lower. All hemoglobin averages at 800 pounds were slightly higher than the average value of 12.0 mg. per 100 ml. reported by Colby and his associates (1950) for beef cattle. Blood creatinine was generally consistent with data in the literature, although many (16 per cent) values were lower and some values higher than those previously reported. Hereford ranges for blood uric acid were consistent with the literature, but Angus males had some values slightly higher and Angus females some values markedly higher than those previously reported for beef cattle.

Blood *hemoglobin* in beef cattle was generally lower and the variability less than in man or the rhesus monkey. Blood *glucose* levels were lower in beef cattle than in man or mouse. Absolute variability of glucose in beef cattle was less than for man or mouse, but on a percentage basis glucose levels had a range similar to those reported for man but much less than the range given for mice (Albritton, 1952). Blood *urea nitrogen* levels were generally lower in beef cattle than in man, and showed somewhat greater variability. *Creatinine* levels were similar in beef cattle and man, although the range was slightly greater in beef cattle. *Uric acid* levels in beef cattle were generally lower than in man but covered a wider range.

Chemical similarities between sexes

There are few statements that can be made with regard to chemical similarities that hold generally for male and female beef cattle as regards hemoglobin, glucose, urea, amino acids, creatinine, or uric acid. The ranges in males and females for each of these chemical parameters overlap extensively, so that even where significant differences are found between male and female averages, sex could only occasionally be correctly correlated with and established by a single chemical determination. It must be kept in mind that some females are similar to some males, while a few females differ from all males, and a few males differ from all females. Beyond the overlap in ranges of chemical parameters, the only similarities in males and females that

hold for both Herefords and Angus is the tendency for hemoglobin to increase as the animals grow from body weights of 500 pounds to body weights of 800 pounds, and the tendency for blood urea to drop over the same period. For both hemoglobin and urea at least one-third of the animals in each category ran counter to the general trend.

Somewhat more restricted statements on similarities between the sexes can be made that apply only to the Hereford and some that apply only to the Angus. Hereford males and females have similar ranges for urea and uric acid at both 500 and 800 pounds body weight. They have a similar average uric acid level at 800 pounds. (Urea averages both at 500 and 800 pounds and the uric acid average at 500 pounds differ.) Hereford males and females have similar blood glucose ranges at 800 pounds body weight and similar amino acid ranges at 500 pounds body weight. Glucose and amino acid averages at 500 pounds body weight are similar.

Hereford males and females have similar hemoglobin averages at both 500 and 800 pounds body weight and hence the increase in blood hemoglobin from 500 to 800 pounds body weight is the same in both sexes. Although average urea levels are different in the two sexes, decreases of similar magnitude in the level of blood urea as the calves grow from 500 to 800 pounds were obtained with both sexes.

Angus males and females have similar hemoglobin averages at 800 pounds and do not differ markedly at 500 pounds body weight. Both male and female Angus show an increase in hemoglobin average from 500 to 800 pounds body weight. They have similar ranges of blood glucose at 500 pounds and similar glucose averages at 800 pounds. Both male and female Angus calves showed a decrease in blood urea while gaining from 500 to 800 pounds body weight. Both sexes had similar ranges and averages of blood creatinine at 500 pounds. They also had similar averages for uric acid at 500 pounds.

Chemical dissimilarities between sexes

Complete similarities in the blood chemistry of males and females are few but differences are many. Sex differences occur with certain aspects of hemoglobin, glucose, urea, amino acids, creatinine, and uric acid. The differences are not the same for Herefords and for Angus. Insofar as data for males and females overlap, there is the possibility that many males do not differ from many females but some individuals differ markedly from the group, and the unusual males are markedly different from the unusual females.

Average *hemoglobin* concentration is generally greater in females than in males at both 500 pounds and 800 pounds body weight. Hereford males have the lower hemoglobin at both 500 and 800 pounds

body weight, and blood hemoglobin was more variable in Hereford females than in Hereford males. Angus males were less variable in respect to hemoglobin than Angus females, and Angus females had the higher hemoglobin averages at both 500 and 800 pounds body weight.

Hereford females were more variable in respect to blood *glucose* than were Hereford males, and had a higher hemoglobin average than did males at both 500 and 800 pounds body weight. Angus females on the other hand had a lower glucose average than did Angus males at both 500 and 800 pounds body weight. Yet the highest blood glucose in Angus was found in a female at 800 pounds body weight.

Hereford males had a lower *urea* average than did Hereford females at both 500 and 800 pounds body weight. Angus males were less variable with respect to urea levels than were Angus females, and had a lower average level of urea at both 500 and 800 pounds body weight.

Hereford males and females had similar average levels of blood *amino acid nitrogen* at 500 pounds, but at 800 pounds body weight Hereford females had the higher average. Hereford females showed an increase in blood amino acids from 500 to 800 pounds body weight, but there was no change in the average for Hereford males. Angus females had higher average levels of blood amino acids than did Angus males at both 500 and 800 pounds body weight. Angus males showed a slight increase in blood amino acid between 500 and 800 pounds body weight, but Angus females had similar averages at both stages of development.

Hereford males were more variable with respect to blood *creatinine* levels than were females at both 500 and 800 pounds body weight. Hereford males had the higher average creatinine at 500 pounds, but the females at 800 pounds body weight had an average similar to that of the males. The average for Hereford males did not alter significantly from 500 to 800 pounds body weight, but there was a clear-cut increase in the average for females. Angus males were more variable than Angus females at 500 pounds body weight, but Angus females were more variable at 800 pounds, yet the averages at both weights were similar.

Hereford males had a higher average level of blood *uric acid* than did females at 500 pounds body weight, but the averages were similar at 800 pounds body weight. Hereford males showed a drop in the average between 500 and 800 pounds body weight but the female averages were unaltered. Angus males and females had similar levels of uric acid at 500 pounds body weight, but from 500 to 800 pounds body weight, average for Angus males decreased and average for

Angus females increased. At 800 pounds body weight Angus females had the higher blood levels. Individual variation and range were greater among the Angus females than among the Angus males.

Comparison of Herefords and Angus

Hemoglobin averages in Herefords were lower than those in Angus at both 500 pounds and 800 pounds body weight. Angus males were less variable than Hereford males and Angus females less variable than Hereford females. Hemoglobin increased similarly in Hereford and Angus males and females from 500 to 800 pounds body weight.

With respect to *glucose* Angus males had a higher level of blood glucose at 500 pounds than did Hereford males. Hereford females were more variable than Angus females. Hereford females had a higher average for blood glucose than did Angus females at both 500 pounds and 800 pounds body weight. Similar increases in blood sugar were found in Herefords and Angus from 500 to 800 pounds body weight.

Angus males varied less than Hereford males with respect to blood *urea*. Averages for Angus males at both 500 and 800 pounds body weight were lower than for Hereford males. Angus females had a higher average urea than did Hereford females at 500 pounds but at 800 pounds averages for Hereford and Angus females were similar. Hereford and Angus males had similar decreases in urea from 500 to 800 pounds body weight, but the decrease for Angus females was far greater than that for Hereford females.

Hereford males had a lower average level of *amino acids* in the blood than did Angus males at 800 pounds, although the averages had been similar at 500 pounds body weight. Angus females had higher levels than Hereford females at both 500 and 800 pounds body weight. Angus males had an increased amino acid level from 500 to 800 pounds body weight but Hereford males did not change; however, Hereford females showed an increase while Angus females showed no change between 500 and 800 pounds body weight.

Hereford males were more variable with respect to blood *creatinine* than were Angus males. Averages for Hereford and Angus males were similar at 500 pounds body weight but at 800 pounds Hereford males had a much higher average. The average for Hereford males did not alter from 500 to 800 pounds but that for Angus males decreased. Hereford females were less variable than Angus females at 500 pounds body weight. Average creatinine for Hereford females was lower than that of Angus females at 500 pounds body weight but at 800 pounds body weight the Angus females had a

slightly higher average (not statistically significant). Hereford females showed an increase in blood creatinine from 500 to 800 pounds body weight, but Angus females showed a decrease.

Hereford males were more variable than Angus males with respect to blood *uric acid*. Angus males had higher uric acid averages than Hereford males at both 500 and 800 pounds body weight. Averages for Hereford and Angus males decreased from 500 to 800 pounds body weight. Angus females were more variable than Hereford females. Angus females had higher uric acid averages than did Hereford females at both 500 and 800 pounds body weight. The uric acid average did not alter in Hereford females from 500 pounds to 800 pounds body weight, but increased markedly in Angus females.

Of the four categories of Hereford and Angus males and females, *Hereford males* were unusual in having the lowest hemoglobin average at both 500 and 800 pounds body weight, a low uric acid, the lowest amino acid averages at 800 pounds, and the highest urea at 800 pounds. These relationships probably have some bearing on the fact that Hereford males are the fastest and most efficient gainers of the four groups (Dahmen, 1952; MacDonald, 1954; Nelms, Williams, and Bogart, 1953).

Hereford females were unusual in having a high uric acid average at 500 pounds and a low average at 800 pounds body weight. They possessed the lowest creatinine at 500 pounds and the highest at 800 pounds. They had the highest glucose average at 800 pounds and were the only group to show an increase in blood creatinine from 500 to 800 pounds body weight.

Angus males were unusual in having a high uric acid level at 500 pounds, the highest glucose at 500 pounds, the highest urea at 800 pounds, but the lowest amino acid and urea averages at 500 pounds, and the lowest creatinine at 800 pounds. They were also characterized by a marked drop in creatinine from 500 to 800 pounds body weight.

Angus females were marked by a high uric acid average and the highest hemoglobin, urea, amino acid, and creatinine levels at 500 pounds, and the highest hemoglobin, amino acid, and uric acid levels at 800 pounds body weight. They had the lowest blood glucose values at both 500 and 800 pounds body weight. The greatest increase in blood hemoglobin averages and the greatest decrease in blood urea averages were developed by Angus females. These characteristics possibly are related to the fact that, of the four categories of Hereford and Angus male and female calves, Angus females have the lowest average rates and efficiencies of gain (Dahmen, 1952; MacDonald, 1954; Nelms, Williams, and Bogart, 1953). The high uric

acid level in Angus females may be an index of inborn chemical peculiarities inimicable to high rates and efficiencies of gain.

Blood chemical changes during growth

Blood hemoglobin averages increased, blood glucose averages increased, and blood urea averages decreased in Hereford and Angus males and females between 500 and 800 pounds body weight. Yet for hemoglobin 11, for glucose 9, and for urea 16, out of 42 individuals, ran counter to the average trend. The decrease in blood urea averages was unusually spectacular for Angus females.

Between 500 and 800 pounds body weight Hereford males and Angus females showed no change in the average blood amino acid nitrogen, while Hereford females and Angus males had an increase in the average. Hereford females developed an increase in average creatinine, while Angus males and females showed a marked decrease. Hereford and Angus males had higher uric acid levels at 500 than at 800 pounds body weight; Hereford females were unaltered and Angus females had an increase. In all cases many individual calves ran counter to the trend.

In the present study, glucose, hemoglobin, and amino acid nitrogen concentration of blood increased from 500 pounds to 800 pounds live weight in every group studied suggesting, possibly, reduced capillary supply, more effective blood flow per capillary per unit of blood pressure when fewer capillaries (indirectly) drain from the aorta per unit of tissue, and/or decreased caloric and nitrogen requirements per unit of tissue. In the case of glucose, reduced pancreatic control per unit weight of tissue with increasing body weight should be investigated as a possible factor controlling the venous level of blood glucose.

In contrast to the constituents mentioned above, blood urea concentrations decreased with the increase in weight from 500 to 800 pounds body weight. This would suggest either a reduced protein intake (and therefore less urea production), reduced utilization of amino acids for growth per unit of tissue, a shift toward relatively less anterior pituitary growth hormone activity per unit of body weight, or an increase in cardiac output of greater proportional magnitude than the increase in body weight.

Because of interaction, often in opposing directions, between sex and breed differences, comparisons of chemical characteristics on a combined basis such as *all Angus*, *all Hereford*, or simply as *beef cattle* frequently have no easily interpretable biological significance.

Summary

1. Blood constituent data from 45 purebred Hereford and Aberdeen Angus bull and heifer calves which were fed on a constant diet through a test period from 500 to 800 pounds body weight have been presented.

2. Normal beef calves exhibited wide variations in concentration of the blood constituents studied at both 500 and 800 pounds body weight, and in all cases where the averages were altered between 500 and 800 pounds body weight there were individuals with trends counter to the average trend.

3. Blood glucose and hemoglobin concentration increased with the increase in weight from 500 to 800 pounds body weight in Hereford and Angus males and females.

4. Blood urea nitrogen concentrations decreased with the increase in weight from 500 to 800 pounds body weight in Hereford and Angus males and females.

5. Blood amino acid nitrogen increased in Hereford females and Angus males, but was unaltered in Hereford males and Angus females.

6. The creatinine average decreased with the increase in weight from 500 to 800 pounds for Angus males and females and increased for Hereford females. The average remained unaltered in Hereford males.

7. Blood uric acid concentration increased with the increase in weight from 500 to 800 pounds for Angus females, but decreased for Hereford and Angus males. The average for Hereford females remained unaltered.

8. Females showed higher concentrations of hemoglobin, amino acid nitrogen, and urea nitrogen than males at both 500 and 800 pounds body weight.

9. Aberdeen Angus calves generally showed higher concentrations of hemoglobin, uric acid, and amino acid nitrogen than Hereford calves.

10. Aberdeen Angus calves showed higher concentrations of blood creatinine than Hereford calves at 500 pounds, but at 800 pounds the reverse was noted.

11. Hemoglobin, glucose, urea, and uric acid levels were lower in beef cattle than those reported for man, and creatinine levels were similar. Individual variability was less in beef cattle than in man for hemoglobin and possibly for glucose. Variability for urea, creatinine, and uric acid was somewhat greater in beef cattle than in man.

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