Reference Values of Blood Parameters in Beef Cattle of Different Ages and Stages of Lactation

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ABSTRACT

Reference (normal) values for 12 blood serum components were determined for 48 Shorthorn cows (2-10 years old) and their 48 calves, 357 crossbred cows (12-14 years old), 36 feedlot bulls and 36 feedlot steers. In addition, hemoglobin, hematocrit, triiodothyronine, thyroxine and cortisol levels were determined for the crossbred cows, and feedlot bulls and steers. Reference values were tabulated according to sex, age and stage of lactation.

Serum concentrations of urea, total protein and bilirubin, and serum activity of aspartate aminotransferase and lactate dehydrogenase increased with age ($P < 0.05$), while calcium, phosphorus and alkaline phosphatase decreased with age ($P < 0.05$) from birth to the age of ten years.

The Shorthorn cows had the highest levels of glucose at parturition ($P < 0.05$) with decreasing levels during lactation. Creatinine concentration decreased during lactation and increased during postweaning. Both lactate dehydrogenase and aspartate aminotransferase levels increased ($P < 0.05$) during lactation. Urea and uric acid were present at higher concentrations in lactating than nonlactating cows ($P < 0.05$).

The values reported, based on a wide age range and large number of cattle, could serve as clinical guides and a basis for further research.

RÉSUMÉ

Cette expérience visait à déterminer des valeurs de référence normales, relatives à 12 paramètres sanguins, chez 48 vaches Shorthorn, âgées de deux à dix ans, et chez leurs 48 veaux, ainsi que chez 357 vaches croisées et âgées de 12 à 14 ans, 36 taureaux et 36 bouvillons de parcs d'engraissement. Les auteurs déterminèrent en plus l'hématocrite, ainsi que les taux d'hémoglobine, de triiodothyronine, de thyroxine et de cortisol, chez les vaches croisées, ainsi que chez les taureaux et les bouvillons de parcs d'engraissement. Ils classifièrent leurs résultats selon le sexe, l'âge et le stade de la lactation. La teneur du sérum en urée, en protéines totales et en bilirubine, ainsi que l'activité de son aspartate-transaminase et de sa lactate-déshydrogénase, augmentèrent avec l'âge ($p < 0,05$), tandis que sa teneur en calcium, en phosphore et en phosphatase alcaline diminua ($p < 0,05$) de la naissance jusqu'à l'âge de dix ans.

Les vaches Shorthorn affichèrent le taux le plus élevé de glucose, au moment du vêlage ($p < 0,05$); il diminua cependant, au cours de la lactation. La concentration de créatinine diminua durant la lactation et elle augmenta après le sevrage. Les taux de lactate-déshydrogénase et d'aspartate-transminase augmentèrent ($p < 0,05$) durant la lactation. L'urée et l'acide urique se retrouvèrent en quantité plus abondante ($p < 0,05$) chez les vaches en lactation que chez les autres.

Les valeurs que rapportent les auteurs se basent sur un grand éventail d'âge et sur un nombre élevé de bovins; elles pourraient par conséquent servir de guide pour une recherche ultérieure.

INTRODUCTION

With the development of automated laboratory instrumentation, the use of certain blood parameters as indicators of the physiological, nutritional, metabolic and clinical status of farm animals is gaining a wider application. In addition, methodology and reagents are becoming more standardized with the use of commercially available diagnostic kits.

For the evaluation of clinical tests in veterinary laboratories a reference basis of normal values of clinically healthy farm animals is essential.

It is well known that variables such as breed, stage of growth, age, reproductive status and stage of lactation have an influence on many blood parameters.

In our research dealing with growth, composition and meat quality aspects, several blood serum components were determined on a relatively large number of beef cattle at different stages of growth and lactation. These blood parameters have been presented in this paper to be added to existing knowledge to benefit both research and veterinary clinical evaluations.

MATERIALS AND METHODS

Test animals consisted of: a) 48 Shorthorn cows, ranging in age from two to ten years, and their 48 calves which were part of an experiment dealing with selection for yearling weight (1), b) 357 crossbred cows, ranging in age from 12 to 14 years. The crosses included Charolais, Limousin or Simmental sires with Hereford, Angus or Shorthorn dams and Hereford x Angus. The crossbred herd was developed by the Research Branch of Agriculture Canada to evaluate the European breeds with

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specific emphasis on the productivity of F_1 crosses and c) 36 crossbred feedlot bulls and 36 crossbred feedlot steers which were born between March and May and were offspring from this crossbreeding program. Representative numbers of the different crosses were allotted to each of the two groups of animals. The calves entered the feedlot at approximately six months of age. After a conditioning period of about one month, the animals were fed to appetite a grass-cereal silage and a rolled barley based concentrate mixture.

Cows were maintained on pasture from June through October with occasional supplementation of forage with hay or silage as required by pasture conditions. During the winter management season (November through May) cows were fed hay and/or silage to NRC standards. During the first six weeks of the pasture season, forage was supplemented with 2 kg/head per day of high energy, high phosphorus range cubes. The Shorthorn calves, born in the spring over a four week period, were weaned at seven months and from weaning to 14 months their ration consisted of silage and grain concentrate (95% of which was barley, oats and dried molasses beet pulp).

The 48 Shorthorn cow-calf pairs were bled 11 times starting at calving and then at approximately one month intervals thereafter. The average days after calving for these 11 bleedings were 1, 43, 80, 109, 137, 165, 218, 247, 275, 303 and 331 days. The crossbred cows were bled in June and September of the same year. Blood samples from the bulls and steers were collected twice, at the start of the feeding period (December) and after 140 days on feed. Blood samples were always collected between 10 a.m. and noon in order to standardize time related variables which are known to influence certain blood components.

All blood samples were taken from the jugular vein using vacutainer tubes. Blood samples were allowed to stand 2 h at room temperature to allow proper clotting. The serum samples obtained after centrifugation were stored at 2°C overnight and analyzed the following morning. All serum components were analyzed by colorimetric techniques on a Technicon SMA II system, according to the methods outlined in the manual supplied by the Technicon Instruments Corporation (1979). Triiodothyronine, thyroxine and cortisol were determined by methods based on the competitive binding principles of radioimmunoassay, whereby the component in the serum and its radioactive labeled (I-125) counterpart compete for binding sites on an antibody which is specific for the component to be determined. Specific procedural details are supplied by the manufacturers of the analytical kits (Amelex™ T3 and T4 kits were supplied by Amersham, Oakville, Ontario; Gammacoat™ (I-125) cortisol kits were obtained from Clinical Assays, Cambridge, Massachusetts). Hematocrit values were determined using anticoagulated whole blood and microhematocrit capillary tubes. Hemoglobin concentrations were measured on whole blood samples by a modified Drabkin method using cyanomethemoglobin reagent. The blood parameters considered in this study and their units are described in Table I.

Reference intervals were calculated by sex, age and stage of lactation subclasses according to the procedures reported by Lumsden and Mullen (2). After outliers were eliminated, using Dixon's statistics, means, standard deviations and normality tests were calculated by the univariate procedure of SAS (3). Nonparametric standard deviations were estimated from the 2.5th and 97.5th percentile (2). Mean separations were performed by Duncan's test (4).

TABLE I. Blood Parameters and Units of Measurement

Blood Parameters	Unit
Urea nitrogen	mmol/L
Glucose	mmol/L
Calcium	mmol/L
Inorganic phosphorus (Pi)	mmol/L
Bilirubin	μmol/L
Alkaline phosphatase (AP)	U/L
Aspartate aminotransferase (AST)	U/L
Lactate dehydrogenase (LDH)	U/L
Creatinine	μmol/L
Uric acid	μmol/L
Protein	g/L
Albumin	g/L
Triiodothyronine (T3)	nmol/L
Thyroxin (T4)	nmol/L
Cortisol	nmol/L
Hemoglobin	g/L
Hematocrit (Packed Cell Volume)	L/L

RESULTS AND DISCUSSION

All animals involved in this study were clinically healthy and the parameters reported represent "normal" values. It is not the intention to discuss in detail the clinical significance and use of these blood components. Their biological-physiological functions will be commented on only to explain apparent differences between groups.

BULLS VS STEERS

The values reported in Table II for steers are similar to those reported by other workers (5,6) except for creatinine, aspartate aminotransferase (AST) and alkaline phosphatase (AP) values which were higher in the present studies. The results for entire males for glucose, urea, total protein and albumin are similar to those reported by Galbraith (7) which were based on two experiments with a total of 12 animals. The differences between the two sexes for the first bleeding are not as pronounced as those for the second bleeding because the effects of recent castration as well as the biological activity of the testes are not fully developed at this stage. Of the 17 components listed under the second bleeding, the levels of 13 components were significantly ($P < 0.05$) different between the two sexes. In both sexes, urea nitrogen, AP, albumin, T4, hemoglobin and hematocrit increased, while lactate dehydrogenase (LDH) decreased with age. Creatinine and T3 increased in the males with age. Of particular interest is the difference in cortisol levels between bulls and steers which is already noticeable in the first bleeding and even more pronounced in the second bleeding. The biological significance of the differences in blood serum levels of cortisol between the two sexes relative to growth and carcass composition has been dealt with elsewhere (8).

CROSSBRED COWS

The values reported in Table III are similar to the general findings from other studies (9,10,11,12). Detailed comparisons with these studies are not

TABLE II. Means and Standard Deviations (SD) of Blood Components for Feedlot Bulls and Steers at Two Bleedings

Blood Component	Bleeding 1 (7.5 months old)						Bleeding 2 (12.5 months old)					
	Bulls[1]			Steers[2]			Bulls[3]			Steers[3]		
	D[4]	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD
Urea nitrogen	G	2.7	0.6[a]	NP	3.5	1.1[b]	G	3.2	0.7[b]	G	4.1	0.8[c]
Glucose	NP	4.4	1.1[a]	G	4.5	0.5[ab]	G	4.8	0.5[b]	G	5.2	0.6[c]
Calcium	G	2.6	0.1	NP	2.5	0.2	G	2.5	0.1	G	2.5	0.1
Pi	G	2.4	0.1[a]	G	2.5	0.2[b]	NP	2.3	0.2[a]	G	2.4	0.2[a]
Bilirubin	NP	2.0	0.6[a]	NP	2.0	0.6[a]	NP	1.9	0.6[a]	NP	1.3	0.6[b]
AP	NP	173.6	60.2[a]	G	168.2	45.8[a]	G	273.6	86.5[b]	G	221.5	70.9[c]
AST	G	130.5	13.7[a]	G	123.4	22.0[a]	NP	123.8	24.6[a]	G	113.6	14.6[b]
LDH	G	1464.9	152.4[a]	G	1436.3	147.5[a]	G	1340.5	137.5[b]	G	1238.6	125.5[c]
Creatinine	G	116.5	10.8[a]	G	116.6	12.3[a]	G	126.8	15.5[b]	G	115.5	11.7[a]
UA	G	65.1	17.4[a]	G	61.9	14.2[a]	G	62.1	10.1[a]	G	44.7	15.1[b]
Protein	G	67.9	3.2[ab]	G	67.8	3.9[a]	G	69.7	2.8[b]	G	69.0	4.4[ab]
Albumin	NP	35.2	2.9[a]	G	36.6	2.1[b]	NP	37.4	3.1[b]	NP	38.7	3.0[c]
T3	NP	3.0	0.8[a]	G	3.0	0.6[a]	G	3.6	0.7[b]	G	3.3	0.7[a]
T4	NP	101.8	28.0[a]	NP	104.8	28.5[ab]	NP	113.2	22.3[bc]	NP	122.9	26.3[c]
Cortisol	G	67.5	38.1[a]	G	106.3	32.3[b]	NP	59.7	27.5[a]	G	151.4	48.8[c]
Hemoglobin	G	118.0	9.0[a]	G	114.0	8.0[a]	G	147.0	16.0[b]	G	141.0	10.0[c]
Hematocrit	G	0.39	0.04[a]	NP	0.38	0.06[a]	G	0.42	0.03[b]	G	0.45	0.04[c]

[1]n = 34-35 for all blood components except bilirubin where n = 23
[2]n = 34-35 for all blood components except bilirubin where n = 26
[3]n = 34-35
[4]D = distribution, G = Gaussian and NP = nonparametric
[a-c]Values followed by different letters within each component are significantly different ($P < 0.05$)

always possible because of the different cattle involved, e.g. dairy cattle vs beef cattle. For those parameters reported on by others (9,11,12), calcium, inorganic phosphorus (Pi) and glucose were very similar, while our values for uric acid were considerably lower than those reported for Holstein cattle (11) ranging in age from 2 to 12.5 yr. Total protein and albumin values in Table III were similar to those reported by Peterson and Waldern, but slightly higher than values from other studies (10,12). The enzyme levels for LDH were higher than those reported by Jenkins (9), but similar to the values for feedlot cattle reported by Ruppanner (6); AP levels in our older cows were lower than in younger feedlot cattle (6). Most reports, including present results, show considerable variation in enzyme levels within a group of animals (6,9,10,11). This variation in enzyme levels has also been reported for pigs (13,14). Because of the nature of enzymes, time and temperature are important variables in their determination. When enzymes are part of a series of blood components of a relatively large number of samples, one hour or more difference in time between analysis of the first and last samples could well be the cause of part of this variation. The same reasoning applies to the effect of temperature fluctuations on enzyme levels. However, as long as this is realized, the determination of these enzymes as part of an overall profile is still valid and valuable. If the determination of certain serum enzymes was the main purpose of a study, a much more stringent control of time and temperature would have been required than is possible when a large number of blood components are to be determined. The hematocrit or packed cell volume values reported in Tables II and III are somewhat lower and the hemoglobin levels similar to those reported previously (15) for young market weight animals. The differences between the two blood samples in Table III represent mainly a lactation effect. The first samples were obtained at the peak of lactation; the second

TABLE III. Means and Standard Deviations (SD) of Blood Components for Crossbred Cows, Age 12-14 Years (n = 351-357), for Two Bleedings

Blood Component	June Bleeding			September Bleeding		
	D[1]	Mean	SD	D	Mean	SD
Urea nitrogen	NP	7.8	2.3[a]	NP	7.5	1.5[b]
Glucose	NP	4.2	0.8[a]	NP	4.4	0.8[b]
Calcium	NP	2.3	0.2	NP	2.3	0.2
Pi	G	1.6	0.3	NP	1.5	0.4
Bilirubin	NP	2.5	1.1[a]	NP	3.3	1.3[b]
AP	NP	67.2	54.8[a]	NP	81.7	78.3[b]
AST	NP	157.9	40.2[a]	NP	147.4	37.8[b]
LDH	NP	1257.5	198.7[a]	NP	1193.9	199.1[b]
Creatinine	NP	103.2	17.9[a]	G	114.1	19.7[b]
Uric acid	NP	44.6	13.4[a]	NP	38.0	11.3[b]
Protein	NP	86.7	7.9[a]	NP	82.4	7.2[b]
Albumin	NP	38.9	3.5[a]	NP	40.4	3.3[b]
T3	NP	1.6	0.5[a]	NP	1.4	0.4[b]
T4	NP	64.4	16.5[a]	NP	61.8	17.6[b]
Cortisol	NP	68.9	28.0[a]	NP	77.2	33.1[b]
Hemoglobin	NP	138.0	21.0[a]	NP	152.0	25.0[b]
Hematocrit	NP	0.38	0.05[a]	NP	0.46	0.08[b]

[1]D = distribution, G = Gaussian, NP = nonparametric
[a,b]Values followed by different letters within each component are significantly different ($P < 0.05$)

samples were collected towards the end of lactation.

SHORTHORN COWS AND CALVES

The values reported in Tables IV and V represent a wide age range in a group of Shorthorn cattle. It is well known that age has a major effect on several of the parameters reported in this study (9,10,14). In Table IV, significant differences in blood component levels have been indicated for the main physiological stages: birth, weaning and approximately one year of age (blood samples 1, 7 and 11 respectively).

Urea nitrogen — The levels from birth to one year of age are somewhat lower than those for animals ranging in age from two to ten years. Beyond two years of age there appears to be no age effect. These results are similar to those reported by Roussel *et al* (10) for one to six year old Jersey cows, but higher than those reported by Huntington (5) for 40 Hereford x Angus steers.

Glucose — Glucose levels were higher ($P < 0.05$) at birth and then decreased gradually to one year of age; there was no age effect beyond two years of age. These results agree with those reported for Jersey cows ranging in age from one to six years (10).

Calcium and Inorganic Phosphorus — Both generally decreased with increasing age beyond one year of age. One of the main functions of these elements is their involvement in skeletal growth in young animals. In older animals there is a decreased need for calcium (Ca) and Pi for this purpose and this is reflected in lower blood levels.

Bilirubin — The bile pigments, bilirubin and biliverden, result mainly from the breakdown of the hemoglobin in the red blood cells. The high levels of bilirubin at birth are likely due to the trauma of the birth process, which often results in varying amounts of extravasation of blood, as indicated by the variation in blood levels (SD = 13.8). After birth, these levels decreased to a low level at one year of age (Table IV). From the age of two years and older, bilirubin levels remained the same (Table V).

Enzymes — Alkaline phosphatase is one of a group of enzymes which catalyzes the liberation of Pi from phosphate esters; it is present in almost all tissues of the body. In mature animals, serum AP originates mainly from the liver. However, in growing animals much of the AP originates from bone tissues. Therefore, the higher serum levels in young animals are indicative of rapid skeletal growth. Roussel (10) also found a

TABLE IV. Means[1] and Standard Deviations (SD) of Blood Serum Components for Shorthorn Calves (n =46-48) at Eleven Periods after Calving

	Period (Average days after calving)																	
		Birth																
Serum		1 (1 day)			2 (43 days)			3 (80 days)			4 (109 days)			5 (137 days)			6 (165 days)	
Component	D[2]	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD
Urea nitrogen	G	4.3	1.6[a]	G	4.1	0.9	G	4.3	0.8	G	3.8	0.7	NP	5.4	1.1	NP	5.6	1.0
Glucose	G	6.5	1.2[a]	G	5.3	0.9	G	6.5	1.3	G	5.5	0.6	G	5.0	0.6	G	4.7	0.5
Calcium	G	2.7	0.2[a]	NP	2.6	0.3	NP	2.8	0.3	NP	2.6	0.2	NP	2.5	0.2	NP	2.5	0.2
Pi	G	2.3	0.2[a]	G	2.7	0.2	NP	3.0	0.4	G	2.5	0.2	G	2.7	0.2	G	2.6	0.2
Bilirubin	NP	13.9	11.4[a]	NP	4.1	1.5	NP	3.3	1.1	NP	4.3	1.2	NP	2.9	0.8	NP	3.0	0.7
AP	NP	430.5	272.3[a]	NP	308.1	114.8	NP	287.0	80.7	G	193.8	46.9	G	206.6	35.8	G	179.5	40.5
AST	NP	103.0	34.7[ab]	NP	85.6	26.4	NP	110.0	28.0	NP	100.8	18.7	NP	121.6	40.1	G	120.5	19.6
LDH	G	1054.7	225.0[a]	G	954.4	151.9	G	1341.0	151.4	G	1238.9	112.9	G	1314.6	121.4	G	1314.3	112.8
Creatinine	NP	111.1	25.7[a]	G	95.6	14.8	G	97.2	12.3	G	90.3	12.2	G	81.1	9.7	G	92.3	9.4
Uric acid	G	50.9	9.9[a]	NP	60.3	14.2	G	92.3	20.7	G	75.5	15.9	G	66.5	12.1	G	56.9	11.6
Protein	G	77.3	14.2[a]	G	64.3	4.7	G	66.8	3.7	G	70.1	3.2	G	67.4	3.0	G	70.8	3.8
Albumin	G	25.3	2.9[a]	NP	37.5	3.6	G	40.5	1.9	G	39.0	2.4	G	38.2	1.7	NP	39.3	3.9
Weight (kg)	G	34.2	3.7[a]	G	60.9	11.6	G	89.3	16.1	G	116.5	20.8	G	143.6	22.7	G	166.4	25.0

	Period (Average days after calving)																	
		Weaning															Yearling	
Serum		7 (218 day)			8 (247 days)			9 (275 days)			10 (303 days)			11 (331 days)				
Component	D[2]	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD	D	Mean	SD
Urea nitrogen	NP	3.3	0.8[b]	NP	4.3	1.0	G	4.2	1.0	G	4.1	1.0	NP	4.4	1.1[a]			
Glucose	G	4.5	0.4[b]	G	4.7	0.5	G	3.9	0.6	G	5.0	0.4	G	4.3	0.6[b]			
Calcium	NP	2.4	0.2[b]	NP	2.5	0.1	NP	2.5	0.2	NP	2.6	0.2	NP	2.6	0.2[c]			
Pi	G	2.6	0.3[b]	G	2.3	0.1	G	2.5	0.2	G	2.3	0.2	G	2.7	0.2[c]			
Bilirubin	NP	2.0	0.6[b]	NP	2.0	0.6	NP	1.8	0.3	NP	2.2	0.8	NP	1.4	0.5[b]			
AP	G	135.9	26.8[b]	G	196.0	48.9	NP	236.7	96.1	G	220.0	56.3	NP	212.6	68.0[c]			
AST	G	94.4	15.6[a]	NP	129.5	64.4	NP	183.0	103.8	NP	137.6	52.0	NP	118.3	29.8[b]			
LDH	G	1137.5	167.9[b]	G	1239.8	132.8	NP	1501.3	309.1	NP	1487.9	226.3	G	1369.1	144.5[c]			
Creatinine	G	104.1	15.2[b]	G	92.9	8.4	G	97.1	10.9	G	98.9	7.9	G	102.1	10.5[b]			
Uric acid	G	48.7	10.4[a]	G	61.9	11.1	G	61.4	11.7	NP	51.3	14.5	G	58.4	14.3[b]			
Protein	G	63.6	3.7[b]	G	67.1	2.4	G	66.5	2.7	G	68.8	3.3	G	69.0	2.9[c]			
Albumin	G	36.2	2.1[b]	G	37.0	2.0	G	36.5	2.2	G	39.4	2.0	G	38.7	1.8[c]			
Weight (kg)	G	212.7	30.6[b]	G	242.1	33.1	G	268.5	39.6	G	290.2	47.8	G	319.2	54.4[c]			

[1]Periods were a significant source of variation ($P < 0.05$; F-test). Differences amongst values for periods 1, 7 and 11 were tested for significance by paired comparisons using the t-test

[2]D = distribution, G = Gaussian, NP = nonparametric

[a,b]For periods 1, 7 and 11 values followed by different letters within each component are significantly different ($P < 0.05$)

TABLE V. Means[1] and Standard Deviations (SD) of Blood Serum Components for Shorthorn Heifers and Cows

Serum Component	Heifers			Cows					
	2 yr old (n = 11)			4-5 yr old (n = 16)			6-10 yr old (n = 21)		
	D[2]	Mean	SD	D	Mean	SD	D	Mean	SD
Urea nitrogen	G	4.9	1.4	NP	5.0	1.6	NP	5.0	2.0
Glucose	NP	3.7	0.8	G	3.7	0.7	G	3.7	0.6
Calcium	NP	2.3	0.2	NP	2.3	0.3	NP	2.3	0.3
Pi	G	1.8	0.3[a]	G	1.6	0.3[b]	G	1.6	0.4[b]
Bilirubin	NP	4.3	2.3	NP	4.2	2.0	NP	4.3	2.1
AP	NP	122.7	72.2[a]	NP	120.6	72.4[a]	NP	179.4	113.4[b]
AST	NP	123.8	33.3[a]	NP	122.6	30.6[a]	NP	132.7	57.8[b]
LDH	G	1224.8	210.3[a]	G	1189.8	188.4[ab]	NP	1165.8	281.2[b]
Creatinine	NP	107.2	24.6	NP	111.1	29.1	NP	106.5	23.8
Uric acid	G	56.5	14.3[a]	G	53.1	10.9[b]	G	55.5	12.0[ab]
Protein	G	71.2	5.8[a]	G	75.4	5.2[b]	NP	75.6	8.5[b]
Albumin	NP	37.2	4.7[a]	NP	39.6	4.4[b]	NP	38.3	4.6[c]

[1]Mean of 11 measurements with outlying values eliminated
[2]D = Distribution, G = Gaussian, NP = nonparametric
[a,c]Values followed by different letters within each component are significantly different ($P < 0.05$)

negative relationship between AP-activity and age.

Aspartate aminotransferase levels showed a great deal of variability within age groups but generally increased with age. This enzyme catalyzes the transfer of an α-amino group from an amino acid to an α-keto acid and is widely distributed in animal tissues. In humans, AST-levels are usually higher in people with muscular dystrophy and after myocardial infarction, indicative of tissue damage (16).

Lactate dehydrogenase is a glycolytic enzyme involved in the reversible conversion of pyruvic acid to lactic acid. The levels at birth appear to be somewhat lower. This trend for AST and LDH to be lower in young animals agrees with results reported by other workers (9).

Creatinine — This compound is the excretion form of creatine compounds. Creatine is phosphorylated in the muscle, forming a reservoir of readily available high energy. Because creatine is contained almost entirely in striated muscle, the amount of creatinine released is related to the muscle mass. High blood levels (more than twice the concentrations reported in the present study) are indicative of nephritis. The serum creatinine levels reported in Table V are similar to those for Holstein cows (11), but slightly lower than those reported for forty crossbred feedlot steers (5).

Uric Acid — Uric acid is derived from the metabolism of nucleic acids via the intermediary purines. The amount of uric acid in most mammals, in contrast to humans, is small as most of this compound is converted in the liver to its more water-soluble oxidation product allantoin. The levels of uric acid fluctuated in the younger animals, but appeared to become stable in the mature cows; there was no clear age effect on uric acid concentrations.

Total Protein and Albumin — Serum proteins constitute a portion of the amino acid pool of the body and as such are believed to be indicative of the nutritional status of the animal. Except for the values at birth, total protein levels were lower ($P < 0.05$) in young animals and higher in mature animals. In Jersey cows (10) total protein also increased with age over a range of one to six years.

Albumin levels were lower at birth ($P < 0.05$) and then increased, but fluctuated somewhat. There was no clear effect of age on albumin levels.

LACTATION EFFECTS

Comparisons of results dealing with the effects of stages of lactation and pregnancy (Table VI) on blood parameters are restricted to those in dairy cattle. It should be realized that lactation effects in dairy cattle, because of the volume and duration of milk production, may well differ somewhat from those in beef cattle. Preliminary results obtained on three lactating beef cows and three lactating dairy cows in their third month of lactation (17) indicated significant differences in certain plasma parameters. In addition, the "physiological" stages compared will often represent a different time interval. The lactating pregnant stage will be longer and the dry stage shorter in dairy cattle compared to those in beef cattle. Jones (18), reporting on a large number of dairy cattle, representing 29 herds, found that in general there was little difference in blood serum parameters between nonlactating and lactating cows; dry cows had slightly lower serum magnesium and urea nitrogen levels. Peterson and Waldern (11) did a detailed study on the effects of physiological stages (lactating non-pregnant, lactating pregnant and dry) on blood parameters in approximately 120 Holstein-Friesian cows. In general, the results presented in Table VI for Shorthorn cows are in agreement with their results and those reported by other workers (19,20). Several of the serum parameters studied were affected by the different states of lactation and pregnancy in similar ways in beef cattle (present data) and dairy cattle. There were, however, some differences. The two elements, Ca and Pi, remained relatively constant throughout the entire period under study (Table VI), while in dairy cattle (11) the serum levels of these two elements were lower during lactation. Glucose levels were reported the same throughout the three stages of lactation (11), while in the present study glucose levels tended to be somewhat higher ($P < 0.05$) at parturition and then declined during lactation. The three enzymes, AP, LDH and AST behaved in a similar way in beef and dairy cattle. In each case (Table VI and references 11,19) enzyme concentrations varied considerably within each stage of lactation; the possible reasons for these fluctuations have been discussed earlier. After parturition AP levels dropped during lactation and increased again towards weaning. Similar results were reported for dairy cattle (11). The LDH concentrations in beef cattle (Table VI) and dairy cattle (11) were lowest during early lactation and then increased. The AST levels in the

TABLE VI. Means[1] and Standard Deviations (SD) of Blood Serum Components for Shorthorn Cows[2] at Eleven Periods after Calving

Serum Component	Period (Average days after calving) Birth 1 (1 day) D[3]	Mean	SD	2 (43 days) D	Mean	SD	Peak Lactation 3 (80 days) D	Mean	SD	4 (109 days) D	Mean	SD	5 (137 days) D	Mean	SD	6 (165 days) D	Mean	SD
Urea nitrogen	G	3.0	0.9[a]	NP	6.3	1.2	G	6.6	0.9[b]	G	5.4	0.9	NP	6.5	1.5	G	6.0	1.0
Glucose	G	4.3	0.8[a]	G	3.8	0.4	NP	3.1	0.6[b]	G	3.7	0.5	G	3.1	0.3	G	2.9	0.4
Calcium	NP	2.3	0.3[a]	NP	2.2	0.2	NP	2.1	0.2[b]	G	2.1	0.2	NP	2.2	0.2	NP	2.2	0.2
Pi	G	1.5	0.2[a]	G	2.1	0.3	G	1.6	0.3[a]	G	1.4	0.3	G	1.7	0.3	G	1.5	0.3
Bilirubin	G	3.1	1.7[a]	NP	3.4	1.0	NP	4.6	1.8[b]	NP	4.0	1.2	NP	3.7	0.9	NP	5.6	1.7
AP	NP	192.9	120.0[a]	NP	155.3	101.4	NP	120.9	65.2[b]	NP	106.2	69.2	NP	135.2	88.0	NP	154.9	100.8
AST	NP	99.3	23.0[a]	G	109.9	14.4	NP	153.6	45.1[b]	NP	139.8	41.2	NP	144.7	50.2	NP	153.6	47.7
LDH	NP	1135.5	305.1[a]	G	1023.4	156.1	G	1239.4	160.9[b]	G	1323.2	213.5	G	1292.5	192.6	G	1296.4	186.3
Creatinine	G	111.4	16.7[a]	NP	99.0	15.8	G	80.6	7.2[b]	G	77.9	9.2	G	89.3	10.6	G	95.8	9.4
Uric acid	G	56.0	13.6[a]	G	57.0	6.8	G	69.0	9.5[b]	G	55.4	14.1	G	61.3	9.6	G	55.1	8.4
Protein	NP	71.3	8.7[a]	G	72.8	4.5	G	79.2	4.4[b]	G	73.0	7.8	G	78.5	3.0	G	77.6	4.6
Albumin	G	39.0	4.1[a]	NP	37.8	4.0	G	40.1	2.3[a]	G	36.0	3.6	NP	39.8	4.3	NP	39.9	4.7
Weight (kg)	G	462.9	93.9[a]	G	449.9	98.9	G	444.1	96.2[a]	G	474.1	86.9	G	485.1	81.6	G	494.1	87.8

Serum Component	Period (Average days after calving) Weaning 7 (218 days) D[3]	Mean	SD	8 (247 days) D	Mean	SD	9 (275 days) D	Mean	SD	10 (303 days) D	Mean	SD	Dry Period 11 (331 days) D	Mean	SD
Urea nitrogen	G	3.4	0.6[c]	G	4.3	0.5	G	3.7	0.5	NP	4.5	0.6	G	3.8	0.5[d]
Glucose	NP	4.1	0.5[c]	G	4.4	0.3	G	4.1	0.3	G	3.7	0.3	G	3.6	0.4[d]
Calcium	NP	2.4	0.2[c]	NP	2.5	0.2	NP	2.5	0.2	NP	2.4	0.2	NP	2.2	0.2[a]
Pi	G	1.3	0.3[b]	G	1.8	0.2	G	1.8	0.3	G	1.7	0.1	G	1.8	0.2[c]
Bilirubin	NP	2.2	1.3[c]	NP	3.2	0.7	NP	3.3	1.0	NP	6.5	2.0	G	7.3	1.8[d]
AP	NP	235.8	147.7[a]	NP	203.7	142.6	G	98.2	50.2	NP	135.3	78.6	NP	130.3	80.8[b]
AST	NP	123.0	30.4[c]	G	119.3	18.0	NP	127.6	31.3	NP	116.3	26.8	NP	98.2	18.8[a]
LDH	G	1205.1	160.1[b]	G	1225.8	103.3	NP	1243.5	227.9	G	1057.0	104.0	G	921.8	99.0[c]
Creatinine	G	127.5	10.6[c]	G	111.1	12.4	G	132.3	14.5	G	140.7	12.2	G	139.2	10.7[d]
Uric acid	NP	50.8	9.7[c]	G	52.7	9.9	G	46.6	8.8	G	46.1	8.9	G	46.6	8.8[c]
Protein	G	76.9	4.3[b]	G	72.0	7.0	G	74.3	4.0	G	72.0	4.1	G	69.7	3.7[a]
Albumin	NP	39.4	3.7[a]	NP	37.6	4.5	NP	38.2	3.5	G	37.8	1.7	G	37.3	2.2[b]
Weight (kg)	G	482.7	88.2[ab]	G	480.6	86.7	G	512.0	89.2	G	509.0	90.3	G	525.4	90.6[b]

[1]Periods were a significant source of variation ($P < 0.05$: F-test). Differences amongst values for periods 1, 3, 7 and 11 were tested for significance by paired comparisons using the t-test

[2]n = 47-48 for periods 1-6; n = 40-41 for periods 7-11

[3]D = distribution; G = Gaussian, NP = nonparametric

[a-d]For periods 1, 3, 7 and 11 values followed by different letters within each component are significantly different ($P < 0.05$)

present study reached a high ($P < 0.05$) towards the second (preweaning) stage of lactation. This is similar to the AST behaviour reported by others (20) who found low AST concentrations at the peak and higher levels towards the end of lactation and in dry cows.

Creatinine levels declined after calving throughout the lactation period and increased again during the dry period after weaning. Peterson and Waldern (11) found no differences in creatinine concentrations among the stages of lactation, but did report that creatinine levels rose in dry cows with increasing days of pregnancy. Kronfeld (20), working with 21 Holstein herds, reported the highest serum creatinine levels during the peak of lactation. In the present study, total protein and albumin levels remained relatively constant throughout. In dairy cattle (11) total protein levels were reported to be higher in dry cows, while albumin concentrations were lower in lactating nonpregnant as compared to lactating pregnant animals. Urea nitrogen and uric acid levels were higher ($P < 0.05$) in lactating cows in both beef cattle (Table VI) and dairy cattle (11).

The values for the serum parameters reported in this study represent a wide range in age, including a relatively large group of older beef cows (12-14 years). The results indicate that both age and stage of lactation in beef cattle have an effect on most of the parameters studied. The results of this study should be of use as a basis for further research and serve as an addition to basic values for clinical guides.

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