SODIUM AND POTASSIUM IN BOVINE BLOOD

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INTRODUCTION

INTRODUCTION

Sodium and potassium are concerned in at least four fundamental physiologic processes: (1) the maintenance of normal water balance and distribution; (2) the maintenance of normal acid-base equilibrium (physiologic neutrality); (3) the maintenance of normal osmotic equilibrium; and (4) the maintenance of normal muscle irritability. Sodium is the major constituent of total base and, therefore, plays a dominant role in this connection. Potassium is the chief cation of muscle and most other cells, while sodium is the chief cation of intracellular fluid. Any considerable replacement of sodium by potassium in extracellular fluids is accompanied by serious disturbances and is eventually fatal. Potassium and calcium modify the most fundamental properties of protoplasm and cells, including permeability of cell membranes, and thus play a role in almost all vital processes.

Many conditions affect the levels of sodium and potassium in cells and plasma. Potassium in blood moves from the cells to the plasma during hemorrhage, asphyxia, muscular exercise, epinephrine administration, adrenocortical insufficiency, and acute intestinal obstruction. Plasma sodium is increased during hyperfunction of the adrenal cortex and anterior pituitary, anemia, and acute intestinal obstruction. Plasma potassium is decreased during rest, anesthesia, insulin administration, hyperfunction of the adrenal cortex and anterior pituitary, diabetes mellitus, familial periodic paralysis, sprue, and severe dehydration. Plasma sodium is decreased during excessive sodium chloride administration,

diabetes mellitus, rheumatic fever, meningitus, lobar pneumonia, pulmonary tuberculosis, and possibly in pregnancy. Pregnancy and menstruation have an effect on sodium and potassium also. The sex hormones have definite sodium and potassium retaining characteristics, and therefore, these ions are normally high but this is not always the case.

Sodium and potassium levels in normal blood, plasma or serum, and cells can be a very valuable diagnostic tool in the hands of the medical technologists. This is evident when one reviews the voluminous literature covering this field of scientific investigation. Chemical Abstracts contain over five hundred references to sodium and potassium in blood over the past fifteen years. The vast majority of these articles deal with human blood values for normal and abnormal subjects. These articles not only deal with blood values, but also with modifications and improvements of the classical chemical methods for the determination of sodium and potassium. There is also a wealth of information on proper techniques for flame photometric analysis of sodium and potassium.

The standard chemical methods for sodium give 2 percent accuracy. However, they are slow and relatively expensive. With chemical methods, the time involved is 3 to 36 hours. This is far too long for clinical purposes. Standard chemical methods depend on the isolation of sodium as an insoluble salt. Sodium is precipitated most frequently as the sodium zinc uranyl acetate, sodium magnesium uranyl acetate, or sodium manganous uranyl acetate. One method precipitates sodium as the sodium pyroantimonate. The precipitation is followed by analysis for some component of the compound that bears a constant ratio to the sodium in the precipitate. This further analysis may be gravimetric, volumetric,

nephelometric, oxidimetric after reduction of uranium, or colorimetric based on the yellow color of the triple salt. Sulfosalicylic acid, or peroxide in alkaline solution may be used to develop the color. All of these procedures depend on a component of the precipitate which is believed to be in constant ratio with the sodium. Washing of the slightly soluble precipitate is considered to be the main source of error.

There are several standard chemical methods for the determination of potassium. Potassium precipitated as the chloroplatinate is considered to be the most accurate method. However, it is very slow and requires preliminary ashing. Cobaltinitrite, silver cobaltinitrite, phospho-12-tungstate and dipicrylamine are also used to precipitate potassium. Here, as in the case of sodium, the precipitation is followed by analysis for some component of the precipitate that bears a constant ratio to potassium. Chloroplatinate can be reduced with metallic magnesium and the resulting chloride determined. Wine red iodoplatinate can be produced by addition of potassium iodide to the chloroplatinate. The iodoplatinate can be determined colorimetrically or titrimetrically with standard thiosulfate. The cobaltinitrite technique is not as accurate but is normally used in clinical laboratories because it is rapid and ashing is not necessary. The nitrite group can be estimated by titration with permanganate, or ceric sulfate and thiosulfate. It can also be estimated by utilizing a diazo reaction or gasometrically. Many colorimetric techniques have been reported in the literature. The nitroso-R-salt is utilized by treatment with choline and ferrocyanide. Phosphotungstic and phosphomolybdic acids (phenol reagent) with glycine, or dimethylglyoxime and benzidine are also used. Methods have been

described for the development of color with thiocyanate, sulfanilic acid plus naphthylamine, and many others.

The flame photometer provides a very rapid method for the determination of sodium and potassium. With proper technique, errors are less than 3 percent. Typical emission spectral band of potassium is at 770 mμ, lithium 671 mμ, and sodium 589 mμ. They are sufficiently distinct to determine in the presence of one another.

It has been stated that a tremendous number of articles on human blood have been published. This is by no means true in the case of bovine blood. There have been fourteen papers published dealing with normal values for sodium and potassium in blood. However, there are large discrepancies in the mean values reported. Most of this work was done by chemical methods. There have been only two papers reporting values by means of the flame photometer. These articles do not by any means give a complete blood picture for sodium and potassium in normal adult dairy animals. The present study was carried out to determine the mean values for sodium and potassium in whole blood, plasma, and cells of normal adult dairy cows and calves. Studies were carried out to determine the effects of rations, environmental conditions, and certain abnormal conditions. A comparison of flame photometric and chemical methods was made. It is hoped that this work will help to clarify and elucidate the rather meager information concerning sodium and potassium in the blood of dairy animals.

HISTORICAL

HISTORICAL

Sodium and Potassium in Humans

Keller (1), in a review on potassium and sodium in biology and medicine, states that the mass of data on sodium and potassium indicates that the behavior of these two elements, regarding their movement under physiological and pathological conditions, can best be explained by the assumption that the basis of their antagonistic nature is caused by their electrostatic nature.

Recently, a division has been made into intracellular components (potassium) and extracellular components (sodium). This division is not strictly accurate because one is always found in the presence of the other, but usually in smaller concentrations.

According to Loeb (2), potassium and sodium are biological antagonists, although both are essential to life.

Table I is a sampling of the values for sodium and potassium in serum of normal human beings that have been reported in the literature.

These values give an average of 144.4 and 4.3 milliequivalents per liter of sodium and potassium, respectively, for normal human serum.

Many pathological conditions have been described in the literature which are associated with abnormal values for sodium and potassium in blood. As methods for the determination of sodium and potassium have improved, the literature on sodium and potassium in blood of individuals with pathological conditions has increased tremendously. Keith et al. (18) reported in 1943 that acute nephritis or marked congestion of the

TABLE I

SODIUM AND POTASSIUM CONTENT OF NORMAL HUMAN SERUM

(Expressed as meq. per liter)

Ref. No.	Year	No. of Detn.	Range	Mean	Deviation Std.	Deviation Av.
			SODIUM			
			Spectrographic			
(3)	1950	100	130.0-159.0	145.0	—	5.5
			Flame photometric			
(4)	1947	107	135.5-153.2	144.0	3.60	—
(3)	1950	70	136.0-158.0	142.0	—	1.8
(5)	1950	20	139.0-152.0	144.5	—	—
(6)	1951	400	135.0-155.0	144.7	3.81	1.91
			Chemical		**Method**	
(7)	1921	18	140.4-152.1	146.2	Kramer and Tisdall	
(8)	1928	14	143.9-150.8	147.3	Kramer and Tisdall	
(9)	1930	10	133.6-137.3	135.0	Barber and Kolthoff	
(10)	1940	15	144.8-151.5	148.2	Dardnell and Walker	
(11)	1948	—	133.0-141.0	137.0	Albanese and Lein	
			POTASSIUM			
			Spectrographic			
(3)	1950	103	3.4 - 4.9	4.1	—	0.27
			Flame photometric			
(4)	1947	107	3.6 - 6.2	4.5	0.45	—
(3)	1950	73	3.6 - 4.8	4.1	—	0.26
(5)	1950	20	3.7 - 5.1	4.5	—	—
(6)	1951	400	3.1 - 5.5	4.2	0.43	0.31
(12)	1951	70	3.7 - 5.3	4.4	0.36	—
			Chemical		**Method**	
(13)	1921	16	4.6 - 5.5	5.0	Kramer and Tisdall	
(14)	1923	6	3.1 - 5.2	4.1	Briggs	
(15)	1933	—	3.0 - 7.6	4.5	Hald	
(16)	1951	5	4.2 - 5.3	4.7	Looney and Dyer	
(17)	1951	100	3.7 - 5.7	4.8	Lochead and Purcell	

kidney raises blood potassium to twice its normal value. Cutillo (19), at the University of Naples, showed that an injection of 30 mg. of vitamin E will decrease serum potassium as much as 30 percent. Widmer (20), in 1944, reported that blood potassium is normal at the beginning of labor and decreases during parturition. The potassium level is highest during uterine contractions. He said that the variations during labor reflect the role of potassium in phosphorylation reactions in muscle metabolism. Many workers have correlated age and sodium and potassium levels in blood. Fiandace (21) reported blood sodium tends to increase slightly with age. Stransky et al. (22), Earle et al. (23), and Brenner and Gralka (24) have confirmed Fiandace's work and also found that there is no variation in potassium due to age or sex. Love and Burch (25) confirmed these facts and also reported no variations due to fasting or stage of menstrual cycle. Variations in red cell sodium and potassium were somewhat related to sex and race. They reported that plasma sodium was lower and cell potassium slightly higher in females. Red cell sodium in negroes was definitely higher than in whites. Bragagnolo and Rotelli (26) and Delaville et al. (27) reported that plasma potassium increases in proportion to the severity of burns. Delaville et al. also reported that anesthesia caused a 15 to 20 percent drop in plasma potassium but that p-aminosalicylic acid and anxiety increased plasma potassium. Bolkelman (28) reported in 1948 that basal metabolism is directly proportional to the concentration of potassium in erythrocytes. Potassium is elevated in hyperthyroidism and drops under the influence of iodine treatment as the rate of metabolism declines. Weller and Taylor (29) stated in 1950 that there is a dynamic interchange of all of the

potassium of cells and plasma. The concentration of potassium is dependent on glucose metabolism. Takeda and Igaku (30) reported in 1949 that fluctuations in temperature influenced the level of serum potassium. Randall et al. (31) reported in 1949 that blood potassium drops during surgery. There have been many reports confirming this. Boulin et al. (32) reported in 1949 that the concentration of sodium in plasma and the potassium in blood are diminished in simple diabetes and acidosis. Blood sodium and serum potassium are very low in diabetic coma. Triolo (33) reported that mechanical or chemical stimulation in the stomach causes increased blood sodium. Romero and Salvago (34) stated that blood potassium is raised in typhoid fever, mumps, malaria, and meningococcal meningitis. Desoxycortisone restored the potassium to normal levels. Viergiver (35) stated that hypopotassemia may be due to inadequate intake, excessive potassium-free fluids, or excessive excretion. Hyperpotassemia may be due to dehydration, renal insufficiency, or tissue breakdown. Bekaert and Demeester (36) found that blood potassium rose during shock. Insulin and glucose given intravenously lower blood potassium. Lecog (37) reported that parathyroid hormone extracts increase plasma calcium, potassium, and sodium. Lans et al. (38) reported in 1952 that potassium is low in blood, but normal in serum and erythocytes in anemia. Dreyfus and Zara (39) reported in 1953 that the ratio of sodium to potassium in plasma is less than normal in Addison's disease. Barilli et al. (40) have reported that blood sodium is low in tuberculosus meningitis.

Methods for the Chemical Determination of Sodium

Streng (41), in 1886, was the first to study the triple acetate sodium salt and to use it as a qualitative tool. Barber and Kolthoff (42) were the first to use this salt for quantitative work in 1928. Their gravimetric technique was not satisfactory for microdeterminations. Barrenscheen and Meissner (43) developed a colorimetric technique for this salt, in 1927, by using potassium ferrocyanide to give a stable red brown color. This method is applicable for biological material. Grabar (44) modified the gravimetric triple acetate method by a preliminary wet ashing with nitric acid and then precipitating the phosphate with ferric ion. Butler and Tuthill (45) modified the Barber and Kolthoff procedure in 1931 by a preliminary precipitation of phosphate as calcium phosphate. In 1921, Kramer and Tisdall (7) used potassium pyroantimonate to precipitate sodium from serum and then determined the sodium gravimetrically. Weinbach (46) in 1935 precipitated sodium zinc uranyl acetate in the conventional way, but determined the sodium by titrating with sodium hydroxide. This method has been utilized to a great extent and is considered the best for clinical purposes. Hoffman (47) precipitated sodium by the Kramer and Tisdall method and then developed an emerald green color by adding boiling water, choline hydrochloride, and sodium ferrocyanide. This method is utilized for use with the photoelectric colorimeter. Dardnell and Walker (10) modified Weinbach's method in 1940 by adding sulfosalicylic acid and sodium acetate to the precipitate and then reading the resulting orange color in a photoelectric colorimeter. Albanese and Lein (11) modified Weinbach's method in 1948 by dissolving the precipitate in water and

determining the sodium colorimetrically. Trinder (48) precipitated sodium according to Weinbach and determined the sodium content by measuring the optical density of the filtrate (unprecipitated uranyl acetate reagent). Seiler et al. (49) described a method for chromatographing sodium and potassium in serum in 1952. A similar method was reported in 1954 by Vanatta and Cox (50).

Methods for the Chemical Determination of Potassium

Kramer and Tisdall (13) precipitated potassium directly from serum by using sodium cobaltinitrite in 1921. The precipitate was titrated with potassium permanganate. Briggs (51) reported a colorimetric procedure in 1923 by adding sulfanilic acid and naphthylamine to the potassium cobaltinitrite to develop a blue color. Sica and Gigante (52) precipitated potassium with dipicrylamine and then used a photometric procedure in 1941. Lochead and Purcell (17) precipitated the potassium in serum as the cobaltinitrite salt in 1951. The cobalt in the salt was used to reduce phosphomlybdic complex in the presence of glycine to give a blue color. Looney and Dyer (53) precipitated potassium with silver cobaltinitrite after the removal of chloride. The salt was decomposed with alkali, acidified to give nitrous acid, diazotized to sulfanilamide, and then coupled to N-(1 naphthyl) ethylenediamine hydrochloride to give a stable red color. Serrano and Santos (54) precipitated potassium with radioactive cobaltinitrite reagent in 1951. A counting technique was used to determine the amount of potassium. In 1953, Barry and Rowland (55) developed a green color with potassium cobaltinitrite by using potassium ferrocyanide. Lindo-Gladding (56) developed the basic

chloroplatinic acid method for potassium in 1923. This procedure is still considered the official method by the Association of Official Agricultural Chemists (57). The material is ashed, dissolved in a minimum amount of hot water and acidified with concentrated hydrochloric acid. Chloroplatinic acid is added and the mixture evaporated to a thick paste. Eighty percent alcohol is added and the mixture filtered and washed. The precipitate is dried and weighed. Shohl and Bennett (58) modified this method in 1928 by adding potassium iodide to the precipitate and titrating the resulting iodoplatinate with thiosulfate. Hald (15) developed a colorimetric technique based on the red color of the iodoplatinate. There have been other modifications, refinements, and colorimetric techniques proposed for the basic methods outlined in this review. However, all the methods used to obtain the values reported in Tables I, II, and III are included.

Physical Methods for Sodium and Potassium

Spectrographic methods have been used for the determination of sodium and potassium by Smith *et al.* (3). However, these instruments are not readily available and are very expensive.

The principle of flame photometry was first used by Lundegardh (59), but it did not become prominent as an analytical tool until 1945, when Barnes *et al.* (60) developed an instrument for industrial purposes. Since that time, a voluminous amount of information has been published concerning proper procedures and techniques of flame photometry. Three main points have been emphasized in the literature concerning flame photometry. First, the burner must be regulated to produce a constant

flame; second, the rate of introduction of the solution into the flame must be constant; and third, the elements will interfere with one another if the concentrations are too high. All workers in this field agree on these points. There are many fine reviews on the flame photometric determination of sodium and potassium. The reviews of Hald (61) and Bernstein (62) are excellent. The three difficulties mentioned above can be almost entirely eliminated by the internal standard method of flame photometry. In this method, a constant proportion of lithium is added to the unknown and standard solutions. By use of a double optical system and matched photoelectric cells, the ratio of the two different spectra is measured under conditions so that any uncontrolled variation in the emission of one element is balanced by a similar alteration in that of the lithium internal standard. In effect, the analyst measures the ratio of sodium or potassium to lithium emission at all times rather than direct total sodium or potassium emission. In this way variations in flame temperature, rate of atomization, and, to a large measure, the interference by other elements in the solution may be compensated. This method is agreed to be the most accurate and is the most popular technique in use at this time.

Sodium and Potassium in Bovine Blood

Table II summarizes the normal values reported in the literature for sodium in bovine serum, plasma, blood, and cells.

Table III presents the normal values reported in the literature for potassium in bovine serum, plasma, blood, and cells.

These data show wide variations for the mean sodium and potassium values reported by the various workers for serum, plasma, blood, and

TABLE II

SODIUM CONTENT OF BOVINE BLOOD

(Expressed as mg. per 100 ml.)

Ref. No.	Year	No. of Detn.	Range	Mean	Method
			Serum		
(63)	1939	80	—	371	Weinbach
(64)	1876	—	—	435	—
(65)	1932	57	209-392	324	Barrenscheen and Meissner
(66)	1898	2	—	160	—
			Plasma		
(67)	1933	—	—	356	Butler and Tuthill
(68)	1936	—	300-320	—	—
(69)	1938	46	213-385	312	Grabar
(70)	1923	2	322-325	324	Kramer and Tisdall
(71)	1951	15	—	145	Flame photometer
			Whole Blood		
(72)	1953	15	—	225	Flame photometer
(64)	1876	—	—	363	—
(73)	1933	2	352-361	356	—
(74)	1935	90	190-398	285	Barrenscheen and Meissner
(75)	1934	96	226-391	275	Kramer and Tisdall
			Cell		
(68)	1936	—	140-150	—	—
(69)	1938	46	119-254	166	Grabar
(66)	1898	2	83-93	88	—

TABLE III

POTASSIUM CONTENT OF BOVINE BLOOD

(Expressed as mg. per 100 ml.)

Ref. No.	Year	No. of Detn.	Range	Mean	Method
			Serum		
(63)	1939	80	--	24.4	Kramer and Tisdall
(64)	1876	--	--	25.4	--
(73)	1933	--	--	21.8	--
(65)	1932	57	16.2-29.4	27.2	Kramer and Tisdall
(66)	1898	2	--	10.7	--
			Plasma		
(76)	1926	31	16.4-41.3	27.3	Briggs
(68)	1936	--	20.0-22.0	--	--
(69)	1938	46	17.4-53.3	33.5	Kramer and Tisdall
(70)	1923	2	17.0-18.1	18.0	Briggs
(71)	1951	15	3.7-4.3	4.0	Flame photometer
			Whole Blood		
(64)	1876	--	--	41.0	--
(73)	1933	2	45.4-54.6	--	--
(74)	1935	73	26.0-177.6	75.0	Kramer and Tisdall
(75)	1934	--	27.7-78.6	49.0	--
(72)	1953	15	--	56.1	Flame photometer
			Cell		
(68)	1936	--	290.0-330.0	--	--
(69)	1938	46	265.0-392.0	320.0	Kramer and Tisdall
(66)	1898	2	28.9-30.0	29.5	--

cells. The flame photometric values do not agree with the values obtained by chemical methods.

Much of the work recorded in Tables II and III is old and a comparison to flame photometric values can hardly be made.

The literature on sodium and potassium in bovine blood is not nearly as profuse as the literature on human blood. However, a review of the work on blood sodium and potassium might help to clear up some of the discrepancies noted in Tables II and III. Du Toit et al. (77) stated in 1934 that low sodium and potassium diets did not affect the sodium or potassium levels in bovine blood. The growth rates were not affected either. Groenewald (74) substantiated Du Toit's work and reported in 1935 that the level of sodium and potassium fluctuate from month to month, but this was not considered abnormal. No differences in blood values were found when the rations were either low or high in sodium and potassium. He also stated that a low blood potassium value could be correlated with an increased sodium value. In 1937, Hamersma (78) reported slight seasonal variations in sodium and potassium. Sodium increased slightly and potassium decreased slightly during winter months. No difference was found due to age or sex and there was no correlation between sodium or potassium and any of the other blood constituents.

Schmidt-Hebbel and Verdugo (79) reported in 1938 that echinococcus infection lowered the level of serum sodium, but that serum potassium was not affected. Reihart (63) reported values for blood sodium and potassium in lactating cows, pregnant and nonpregnant heifers in 1939. The data indicated that blood sodium is higher two hours after milking,

but no change was observed two hours before or during milking. No differences were noted between pregnant and non-pregnant heifers from the normal values. Duncan et al. (80) showed definite seasonal variations in plasma magnesium in dairy calves in 1950. This work substantiates the finding of Hamersma (78).

Sellers et al. (71, 81) reported in 1951 that both plasma sodium and potassium increased when either potassium and sodium chloride was administered. They also reported no changes in plasma sodium and potassium through the parturition period with the administration of large doses of diethylstilbesterol. Ward et al. (82, 83) reported in 1952 that blood sodium remains nearly constant through parturition, but a slight increase was noted from five days prepartum to the day of parturition. There was a marked decrease in sodium for three to twelve days postpartum when milk fever developed. Blood sodium increased and potassium decreased when the milk fever animals were placed under treatment. Ward states that these findings are not conclusive because of the limited amount of data.

Many pathological conditions have been reported that affect sodium and potassium in human blood. It seems reasonable to expect that some of these same conditions might affect the concentration of sodium and potassium in bovine blood in the same manner.

From the findings reported here, it is evident that much more work must be done to clarify the sodium and potassium blood picture for dairy animals.

EXPERIMENTAL

EXPERIMENTAL

Animals

Sodium and potassium were determined on both whole blood and plasma from 154 cows and 12 newborn calves. Most of these animals were of the Holstein and Jersey breeds. A total of 723 samples of blood were drawn from these animals. The normal values for dairy cattle were established by taking a total of 200 blood samples from 100 normal adult dairy animals. No attempt was made to pick animals in a certain stage of lactation or pregnancy. This was done deliberately, in order to get as representative a sampling as possible. Ten sets of identical twins were used in an experiment designed to study the effects of different rations on sodium and potassium values. Twelve calves were studied from birth to 12 weeks of age to establish normal values for newborn calves. Blood samples were taken from the calves at birth, three days after birth, and at weekly intervals until the animals were 12 weeks old. Blood patterns for six of the calves' dams were studied. Blood samples were taken from three weeks before parturition to three weeks after parturition.

Two Jersey cows with endematous udders were studied to establish the sodium and potassium blood picture for these animals. The blood picture on 23 sterile heifers and cows was studied to see if there was any divergence from the normal blood pattern. These sterile animals were thoroughly examined by veterinarians and animal pathologists.

They found no physical abnormalities. Blood patterns were determined on a set of identical triplet calves. This was done to see if there were any differences between the three animals.

Handling of Blood

Fukawa et al. (83) reported that plasma potassium varies with the method used for sampling. Potassium increases above normal when constriction is used to distend the vein. Baumann and Hermann (84) found that plasma potassium values were not the same in venous, capillary, and arterial blood. Other workers have reported that changes take place in blood on standing. Some of the reports are conflicting but most workers agree that plasma or serum potassium increases after 12 hours of standing, although the changes do not take place as rapidly when the blood is refrigerated. Wise et al. (85) reported that oxalate and citrate anticoagulants shrink red blood cells. Ryssing (86) found that anaerobic methods were not necessary. He reported that 0.5 to 1.0 mg. of heparin per 10 ml. of blood was the most desirable anticoagulant. He reported also that serum potassium and heparinized plasma potassium values were the same. It is generally accepted that hemylosis increases serum or plasma potassium.

With the preceeding information in mind the following procedure was set up. Heparin was chosen as the anticoagulant for this work. Citrate or oxalate salts could not be used because of mineral contamination. One mg. of heparin in a 15 ml. heavy-walled Pyrex test tube was satisfactory. Not one tube clotted throughout the entire experiment. Heparin does contain sodium, but the dilution of whole blood and plasma is so large that no sodium contamination by heparin was detected.

The animals were bled about 9:00 a.m. The lactating animals had been milked at 4:30 a.m. No interference was noted as reported by Reihart (63), who reported increased sodium values 2 hours after milking. The blood was withdrawn from the jugular vein and carefully run down the side of the tube to prevent hemolysis. The tube was filled almost to the top. It was then corked and carefully inverted a few times to mix the blood and the anticoagulant. Careful inversion did not cause hemolysis. New corks were used to prevent contamination of the blood. The samples were brought to the laboratory immediately for analysis. If it was necessary for the blood to be stored, it was stored under refrigeration. This was necessary in a few cases during the studies on parturition and new-born calves. The samples of blood were discarded if hemolysis was evident or if they were stored for more than 12 hours. Each blood tube was gently inverted ten times to assure a representative sample. Aliquots of whole blood were taken immediately after inversion for cell volume and whole blood sodium and potassium determinations. A clean pipette was used for each sample. The remainder of the blood was centrifuged at 3,000 r.p.m. for 30 minutes. The plasma was carefully examined for signs of hemolysis. Hemolysis was observed in only three samples during this work. Citrated blood was also taken with the same precautions that were observed with heparinized blood. The citrated blood was used to determine cell volume.

Analytical Procedure

All reagents used in this work were C.P. All laboratory glassware used in this work was made of Pyrex. The bottles used for stock and

standard solutions were made of "No-Sol-Vit" glass. All the glassware was cleaned with chromic acid cleaning solution and thoroughly rinsed with triple distilled water. This procedure was deemed necessary to prevent sodium contamination. Blanks were run constantly with the triple distilled water plus the necessary amounts of reagents to check for contamination.

Cell volume determination. The thoroughly mixed blood was pipetted into the hematocrit tube by means of a Wintrobe filling pipette. The hematocrit tubes were centrifuged at 3,000 r.p.m. for 75 minutes. This period of time was found necessary to completely spin down the cells to a constant volume.

Table IV presents the mean cell volume values determined from citrated and heparinized blood. The percent differences vary considerably from one month to the next. These data are in agreement with the work of Wise et al. (85) who reported that oxalate and citrate anticoagulants shrink red blood cells. It is felt that the high concentration of citrate disturbs the electrolyte balance of the blood. Water moves from the cells to the plasma in order to restore the balance, thus causing a shrinkage of the red blood cells.

Chemical method for sodium. Sodium was determined chemically by the method of Weinbach (46). This method was chosen because it is considered best for clinical purposes and also because much of the work reported in the literature was done by this method. Difficulty was experienced in finding the proper end point for the titration of the sodium zinc uranyl acetate with sodium hydroxide. The indicator used was phenolphthalein. Weinbach stated that the end point is just barely

TABLE IV

A COMPARISON OF MEAN CELL VOLUMES FROM CITRATED AND HEPARINIZED BLOOD[1]

No. Samples	Citrate	Heparin	Percent Difference
10	33.3	35.9	7.8
10	35.5	40.7	14.6
20	31.4	37.0	17.8
20	31.4	38.2	21.6
20	28.8	34.0	18.1
20	34.1	38.5	12.9
30	31.6	35.8	13.3
20	27.3	33.9	24.2
20	31.7	36.7	15.8
10	28.9	36.0	24.6
10	32.5	37.2	14.5
10	38.2	43.6	14.1
Av.	31.6	36.9	16.8

[1] The heparinized blood was used for the data presented in Tables IX and X.

a preceptible pink. The color of the sodium salt is yellow, so the change is actually from yellow to salmon to pink. Even with the aid of blanks, it was found that the end point was extremely difficult to determine accurately. Because of the difficulties experienced with this end point a colorimetric procedure was adopted.

The sodium was precipitated and washed according to Weinbach's procedure. The precipitate was transferred quantitatively to a 50 ml. volumetric flask by repeated additions of small amounts of distilled water. The flask was made up to volume and thoroughly mixed. The absorption curve for sodium zinc uranyl acetate was determined by means of a Beckman Model B spectrophotometer. This curve is given in Figure 1. The maximum absorption is at 350 mμ. Albanese and Lein (11) used a similar method and found that the maximum absorption was at 420-440 mμ.

A set of standard sodium solutions containing 1.0, 0.8, 0.6, 0.4, 0.2, and 0.0 mg. percent were treated as in Weinbach's procedure. They were made up to a volume of 50 ml. and the optical density determined at 350 mμ. with the Beckman Model B spectrophotometer. The resulting curve followed Beer's Law. The color was stable for 24 hours, but a slight increase occurred after 48 hours. Figure 2 gives the curve for optical density plotted against the milligrams percent of sodium.

Table V compares flame photometric, spectrophotometric, and chemical methods for the determination of sodium in whole blood and plasma. The flame photometric and spectrophotometric values show excellent agreement. The values determined chemically do not agree very well. They also show a larger standard deviation. It is felt that the failure of agreement with the chemical method is due in large part to the difficulty experienced with the end point.

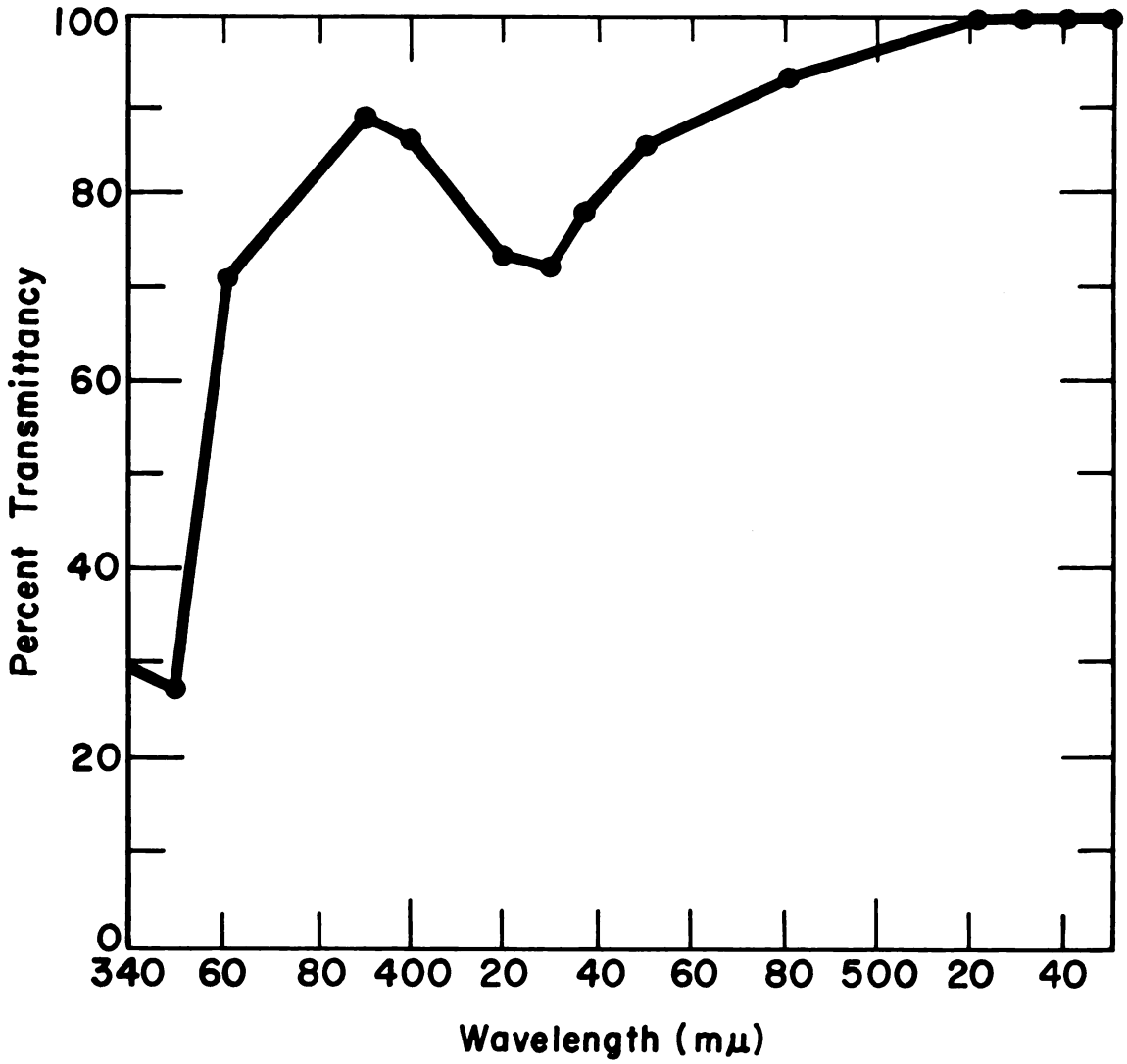

Figure 1. Absorption spectrum of sodium zinc uranyl acetate solution containing 1 mg. % of sodium.

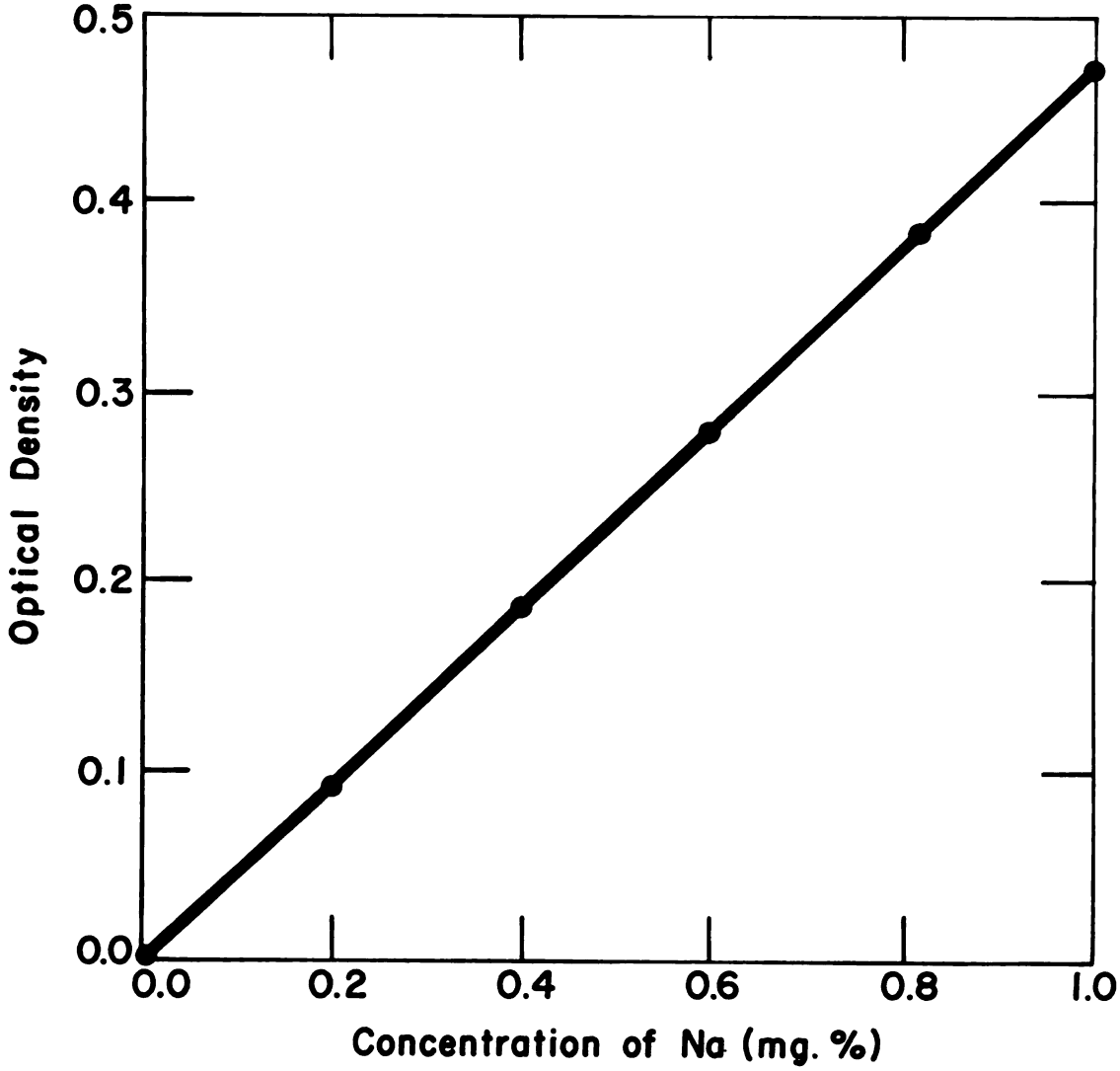

Figure 2. Absorption curve for standard sodium zinc uranyl acetate solutions.

TABLE V

COMPARISON OF FLAME PHOTOMETRIC, SPECTROPHOTOMETRIC AND CHEMICAL METHODS FOR SODIUM

(Expressed as mg. per 100 ml.)

Flame Photometer	Spectrophotometer	Chemical
	Whole Blood	
271.5	268.0	247.6
261.0	263.0	246.6
261.8	264.8	244.8
266.8	262.3	280.0
260.8	265.0	270.5
266.0	263.4	266.9
265.3	270.0	226.8
267.5	267.0	230.0
269.5	270.8	235.2
262.0	259.3	241.6
266.0	264.8	245.4
258.5	260.9	265.0
Av.[1] 264.7 ± 0.91	264.9 ± 0.82	250.0 ± 3.9
	Plasma	
344.5	345.0	330.0
320.0	322.0	328.2
322.8	327.2	341.6
340.0	338.0	337.0
344.5	349.0	385.4
363.0	360.0	388.4
334.8	335.6	373.5
342.0	339.1	311.7
351.5	353.5	319.2
339.0	337.5	384.7
332.5	334.3	417.9
330.8	335.4	397.6
Av.[1] 338.8 ± 2.6	339.7 ± 2.3	359.6 ± 9.0

[1] Average values with standard deviation.

Chemical method for potassium. Potassium was determined chemically by the chloroplatinate procedure outlined by Peters and Van Slyke (87). This procedure is the method of Shohl and Bennett (58). The ashing procedure, precipitation of chloroplatinate, and titration with thiosulfate were followed exactly as outlined by Peters and Van Slyke. This method was employed because it has been used in clinical laboratories for many years.

Table VI presents the comparison of the flame photometric and the chemical method for the determination of potassium in whole blood and plasma. The agreement is poor between the two methods. The chemical method is difficult and requires a large number of quantitative transfers. It is felt that a great deal of experience is necessary before high accuracy can be expected. The values at the end of Table VI give better agreement than those at the beginning. The values at the beginning of Table VI were the first ones determined.

Preliminary treatments for whole blood and plasma. Kingsley and Schaffert (88) reported that trichloroacetic acid precipitation causes a loss of sodium and potassium. Trichloroacetic acid precipitation, wet ashings, and dry ashings were carried out on the same blood sample. The trichloroacetic acid precipitation was carried out as outlined in the subsequent section dealing with flame photometry. The wet ashing procedure was carried out according to Peters and Van Slyke (87). It was the same method used for the ashing in the chemical method for potassium. The dry ashing method was a modification of the procedure outlined by Hunter (89). The blood or plasma plus 1 ml. of 4N sulfuric acid was evaporated and charred in a platinum crucible over a steam

TABLE VI

COMPARISON OF FLAME PHOTOMETRIC AND CHEMICAL METHODS FOR POTASSIUM

(Expressed as mg. per 100 ml.)

Flame Photometer	Chemical	Flame Photometer	Chemical
Whole Blood		Plasma	
76.0	47.3	23.6	19.7
77.3	200.0	23.5	22.5
86.8	179.3	25.4	25.6
73.8	141.0	20.3	21.2
78.5	114.8	20.3	16.5
81.5	97.0	25.4	22.4
75.9	100.0	25.0	21.9
73.8	77.5-67.5[1]	24.6	20.0
76.8	65.0-75.0[1]	26.0	21.0
76.5	83.4	22.0	27.1-18.4[1]
72.3	85.0	21.2	15.8-17.4[1]
73.5	78.7	23.5	18.4-24.0[1]
Av.[2] 76.9 ± 0.77	100.8 ± 8.9	Av.[2] 23.4 ± 0.46	20.8 ± 0.67

[1] Duplicates were run when enough sample was available.

[2] Average values with standard deviation.

bath. The crucible was placed in a muffle furnace and heated at 450° C. until a white ash remained. The solutions from the wet ashing and the dry ashing were made up to an appropriate volume and filtered. Stock lithium chloride was added prior to dilution to give a concentration of 10 mg. percent in the final solution. The sodium and potassium in these solutions were determined by the flame photometric procedure outlined in the subsequent section dealing with flame photometry.

Table VII presents sodium values in whole blood and plasma determined flame photometrically with preliminary trichloroacetic acid precipitation, wet ashing, and dry ashing. The standard deviation is not included because some of the samples were from very young calves and show large variations. The agreement for the preliminary treatments of trichloroacetic acid precipitation and dry ashing is excellent. The wet ashing procedure gave higher values. The wet ashing was done in Pyrex test tubes by means of sulfuric acid, Superoxol, and heat. Blanks were run and the amount of sodium present taken into account in the calculation. However, it is felt that the higher value was due to sodium dissolved from the glass during the wet ashing procedure.

Table VIII presents potassium values in whole blood and plasma determined flame photometrically with preliminary trichloroacetic acid precipitation, wet ashing, and dry ashing. The data indicate that all three preliminary treatments yield the same values. These studies on preliminary treatments do not substantiate the work of Kingsley and Schaffert (88) who reported that trichloroacetic acid precipitation caused a loss of sodium and potassium.

TABLE VII

VALUES FOR SODIUM BY TRICHLOROACETIC ACID PRECIPITATION, WET ASHING, AND DRY ASHING[1]

(Expressed as mg. per 100 ml.)

TCA Precipitation	Dry Ashing	Wet Ashing
	Whole Blood	
277.5	280.0	319.5
255.0	260.0	235.3
249.8	251.5	280.0
267.4	262.3	300.0
293.6	290.0	260.5
284.5	285.0	270.0
Av. 271.3	271.5	277.6
	Plasma	
341.5	345.0	365.0
342.3	344.0	357.5
352.0	350.0	372.8
335.6	338.2	300.0
340.0	338.0	360.0
339.7	343.5	375.0
Av. 341.8	343.1	355.1

[1] Determined by flame photometer.

TABLE VIII

VALUES FOR POTASSIUM BY TRICHLOROACETIC ACID PRECIPITATION, WET ASHING, AND DRY ASHING[1]

(Expressed as mg. per 100 ml.)

	TCA Precipitation	Dry Ashing	Wet Ashing
		Whole Blood	
	54.8	55.9	50.3
	180.3	180.6	182.3
	141.8	144.0	145.0
	100.3	98.0	96.4
	52.0	54.6	50.3
	61.0	60.0	62.3
Av.	98.4	98.9	97.8
		Plasma	
	23.0	24.0	24.8
	28.5	29.0	26.2
	24.4	24.1	25.3
	24.0	22.9	23.3
	20.2	21.6	18.9
	22.3	22.3	23.0
Av.	23.7	23.9	23.6

[1] Determined by flame photometer.

Tables V and VI indicate that the chemical methods for sodium and potassium were not as reliable as the flame photometric method. The spectrophotometric method for sodium was as reliable as the flame photometric method but it is time consuming. Tables VII and VIII indicate that the trichloroacetic acid and dry ashing preliminary treatments were satisfactory, but the ashing procedure is time consuming; therefore, the trichloroacetic acid preliminary treatment and the flame photometric procedure were used for the remainder of the studies.

Flame photometric determination of sodium and potassium. Sodium and potassium were determined by the internal standard method. A Perkin-Elmer flame photometer, Model No. 52-A, with a red-sensitive phototube and an acetylene flame was used to measure the amounts of sodium and potassium in the solutions.

There are two basic procedures that can be followed for the determination of sodium and potassium in erythrocytes. One method is to centrifuge the blood and take an aliquot of the cells. The cells are diluted with water and hemolyzed. This solution can either be used for the determination or the protein can be removed first. This method has the disadvantage in that it is difficult to completely separate all of the plasma from the cells, thus introducing an error that is difficult to correct. This method gives high cell sodium values and low cell potassium values. The other method is to determine the whole blood sodium and potassium and then determine sodium and potassium in the plasma. The values for cells are found by calculation, using the whole blood, plasma, and cell volume values according to the following formula:

$$\text{Cell sodium} = \frac{\text{Blood sodium} - (\text{Plasma sodium} \times \text{plasma volume})}{\text{cell volume}} \quad (1)$$

The procedure used for the flame photometric determination is a modification of Hunter's (89) method. Thirty ml. of distilled water and 10 ml. of a stock lithium chloride solution (internal standard) were pipetted into standard taper 100 ml. volumetric flasks, (Kimble Exax, retested). The stock lithium solution was 100 mg. percent. This gave a final lithium concentration of 10 mg. percent. The standard sodium and potassium solutions also contained 10 mg. percent of lithium made from the same stock lithium chloride solution. Twenty ml. of distilled water and 5 ml. of the stock lithium solution were pipetted into 50 ml. standard taper volumetric flasks. Two ml. of mixed whole blood were pipetted slowly into the 100 ml. flask. One ml. of plasma was pipetted slowly into the 50 ml. flask. Five ml. of plasma were pipetted slowly into a similar 50 ml. flask. The blood and plasma were pipetted slowly in order to get an accurate measurement because these solutions adhere to the sides of the pipette due to their high viscosity. The sides of the flasks were washed down with distilled water. The flasks were stoppered and allowed to stand for 4 hours to make sure that hemolysis was complete. Five ml. of 20 percent trichloroacetic acid were pipetted into the 100 ml. flasks and 4 ml. were pipetted into the 50 ml. flasks. The flasks were then made up to volume with distilled water. A few drops of ethyl alcohol were introduced into the neck of the flask to prevent foaming of the denatured proteins and assure accurate dilutions. The flasks were mixed at intervals for a period of 24 hours. This period of time allowed for complete precipitation of the blood proteins. It also provided time for the sodium and potassium ions to equilibrate in the solution, thus preventing

occlusion of these ions in the precipitated proteins. The solutions were filtered through Whatman No. 42 filter paper. The resulting filtrates were water clear and ready for analysis. The filtrate from the 100 ml. flask was used for whole blood sodium and potassium. It contained from 1 to 3 mg. percent of potassium and from 4 to 7 mg. percent of sodium. The 50 ml. flask containing 1 ml. of plasma was used for sodium. It contained from 6 to 7 mg. percent of sodium. The 50 ml. flask containing 5 ml. of plasma was used to determine potassium. This solution contained from 1 to 3 mg. percent of potassium. The following dilutions were used: whole blood sodium and potassium, 1 to 50 ml.; plasma for sodium, 1 to 50 ml.; and plasma for potassium, 1 to 10 ml.

Three stock solutions were prepared: sodium chloride, potassium chloride, and lithium chloride, each containing 100 mg. percent of their respective cations. These stock solutions were used to prepare the standard solutions for the standard curves. Sodium standard solutions were prepared to contain 0.0, 2.0, 4.0, 6.0, and 8.0 mg. percent of sodium. Potassium standard solutions contained 0.0, 1.0, 2.0, 3.0, and 4.0 mg. percent of potassium. All standards contained 10.0 mg. percent of lithium. The stock and standard solutions were stored in standard taper "No-Sol-Vit" glass bottles to eliminate sodium contamination. When it became necessary to make up new stock solutions, these solutions were carefully checked against the old stock solutions and all new standard solutions were prepared. When a new standard solution was needed, it was carefully checked against the old standard solution before it was used to prepare the standard curves.

Pressures of 4 pounds per square inch for acetylene and 10 pounds per square inch for air were found to be very satisfactory for the production of a clear blue flame. The atomizer system also worked well at this air pressure. The purity of acetylene varied from one tank to the next and atmospheric conditions varied daily. Changes in acetylene and atmospheric conditions have a drastic effect on readings obtained from a flame photometer. Changes in acetylene and air pressure also affect the readings obtained. The cleanliness of the burner and atomizer systems are of utmost importance in the successful operation of the flame photometer. Clogging of the atomizer system gives reduced readings and low results. Because of the varying conditions which affect the operation of the flame photometer, a standard curve was run with every set of samples determined. Many workers do not feel that this is necessary and that only a check of one or two points on the standard curve is sufficient. It was felt that the reliability and confidence gained in the results was well worth the extra time and effort. The atomizer and burner systems were thoroughly cleaned before each set of samples was run. A steady flow of solution through the atomizer system and thus a steady introduction into the burner is essential for reliable results. Some workers feel that diluted whole blood and plasma should be introduced directly into the atomizer system because it eliminates the danger of sodium and potassium occlusion by the denatured protein. This procedure causes a continual clogging of the atomizer due to the high viscosity of blood and plasma, and thus, changes the rate of flow into the burner.

The instrument was turned on 30 minutes prior to operation as a warm up period. The air compressor was turned on at this time to build up pressure. The pressure in the tank was maintained between 75 and 100 pounds per square inch. The flame was always inspected for carbon flecks or other abnormalities. When trouble was found, burner adjustments were made to correct it. Depending on which element was to be determined, a solution of this element was introduced into the atomizer. The wave length of the instrument was adjusted until the galvanometer gave a maximum deflection. This insured the proper wave length setting of the instrument. Next, the null point of the instrument was set on a galvanometer reading of 49 by using distilled water. This null point was used throughout the rest of the determination. The highest standard (top standard) was introduced with the internal standard dial set at the maximum reading of 100. The galvanometer was adjusted back to the null point by means of the gain controls. The null point was checked again with distilled water at the gain settings of the top standard. The distilled water null point should not change throughout the entire determination. The top standard was checked again and then the lower standards were run. The gain setting is not changed while running the lower standards. The galvanometer was adjusted to the null point by adjusting the internal standard dial. The reading of the internal standard dial is proportional to the concentration in the standard solution. If the concentration of the standard is 75 percent of the top standard, the internal standard dial reading will be around 75. It is evident that an accurate gain setting for the top standard is of utmost importance. This gain setting will change due to changes

in resistance and other electronic variations during extended operation of the instrument. With this in mind, it was decided to always check the top standard and adjust it to the null point by means of the gain controls with the internal standard dial set at 100 before each lower standard was checked. The standards were checked periodically throughout the determination of the unknowns. The top standard and one lower standard were checked after six unknowns were run. A minimum of four checks were made on each lower standard in order to insure the best possible standard curve. The checks had to agree within one unit of the internal standard dial in order to be acceptable for inclusion in the average reading used to make the standard curve. The blood and plasma filtrates were run in the same manner as the standards. The internal standard dial was adjusted until the galvanometer was steady on the null point. Then the reading of the internal standard dial was recorded. Two readings were taken for each sample and averaged. The readings had to agree within one unit of the internal standard dial. These readings were used to find the mg. percent in the filtrate from the standard curve. Figures 3 and 4 are typical standard curves for sodium and potassium, respectively.

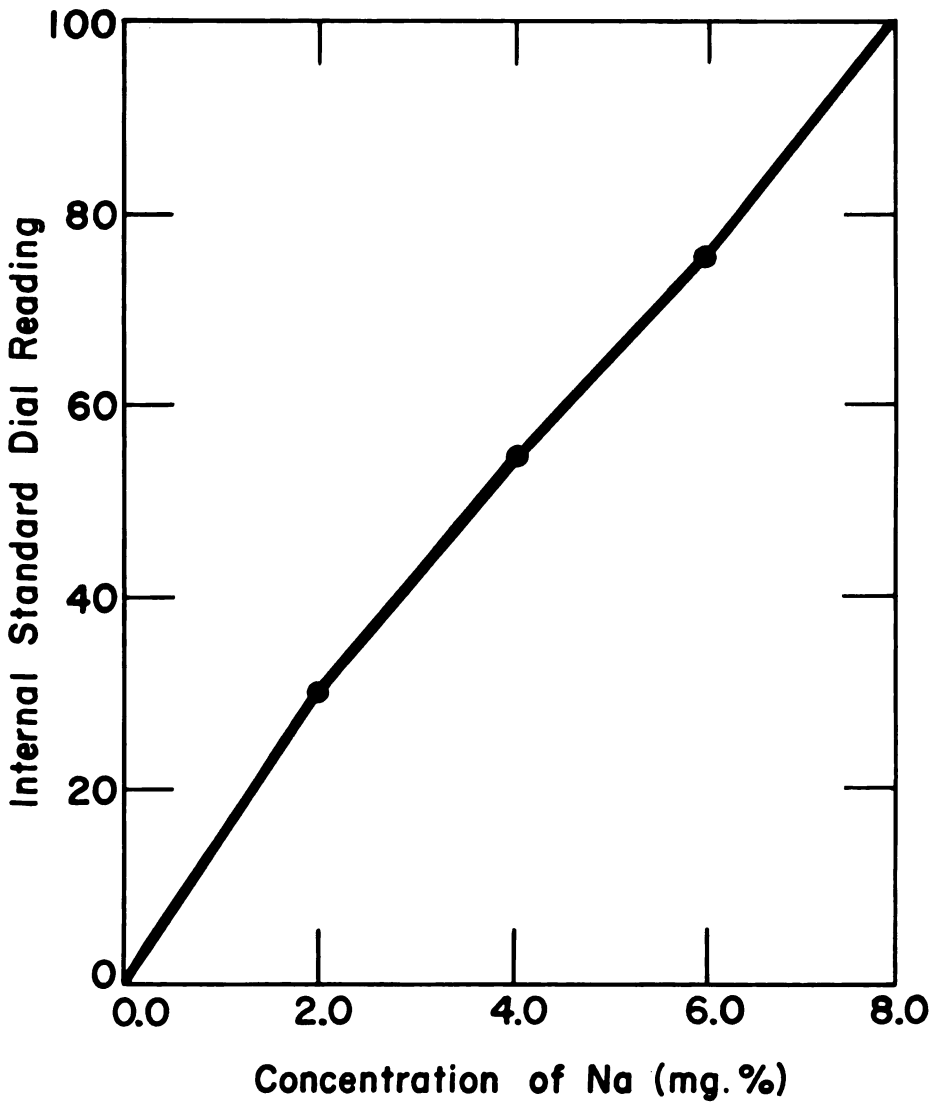

Figure 3. Standard calibration curve for blood sodium (all samples were diluted to contain between 2.0 and 6.0 mg. %).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Sodium and Potassium Content of Blood of Normal Adult Dairy Cows

The data presented in Tables IX and X are the mean sodium and potassium values obtained for whole blood, plasma, and cells for 200 determinations on 100 normal adult cows. The values presented are arranged on a monthly basis to determine whether seasonal variations were evident. Duncan et al. (80) found a seasonal variation in plasma magnesium and Hamersma (78) reported slight increases in sodium during winter months. The average values reported in Tables IX and X do not agree very well with the values reported in Tables II and III which summarized the values reported in the literature This is particularly evident in the case of cell sodium and potassium. Cell sodium showed fairly large monthly variations. However, the mean whole blood and plasma sodium values did not show large variations from month to month. This is in direct contrast to Groenewald (74), who reported large monthly fluctuations. The range for the various constituents seems to be fairly consistent from month to month. It has been noted that sodium and potassium levels for individual adult animals remain quite constant over long periods of time. The standard deviations are reasonably small. This is an indication that the mean values reported are quite reliable.

Table XI presents the ratios of sodium to potassium in whole blood, plasma, and cells. The ratio of sodium and potassium between

TABLE IX

MEAN MONTHLY VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NORMAL ADULT COWS

(Expressed as mg. per 100 ml.)

Month	No. of Detn.	Blood	Range	M.D.	Plasma	Range	M.D.	Cell	Range	M.D.
Jan.	10	292.1	255.0-319.0	21.4	356.0	348.0-365.0	4.4	191.8	124.6-256.7	24.0
Feb.	10	290.3	252.0-314.5	8.9	348.3	336.0-362.0	5.0	180.6	139.0-205.4	17.5
March	20	280.2	261.0-297.1	6.3	339.8	324.0-356.5	5.7	178.5	148.8-215.1	15.0
April	20	280.3	254.0-289.5	6.1	337.3	322.0-374.0	9.3	173.9	141.7-207.0	15.0
May	20	281.9	270.5-304.0	6.2	342.6	324.5-362.5	5.7	167.6	122.9-205.9	14.0
June	20	281.0	255.0-303.5	8.1	338.0	323.0-354.0	6.1	169.8	137.9-200.7	12.4
July	30	283.2	253.8-325.0	12.2	344.6	320.5-371.5	10.0	190.0	155.1-227.4	17.2
Aug.	20	280.2	237.0-297.0	10.0	344.3	327.0-396.3	9.4	183.6	143.9-205.3	12.0
Sept.	20	293.5	268.0-308.5	10.6	337.0	314.3-359.0	7.4	200.3	164.5-221.4	11.0
Oct.	10	277.0	267.0-289.0	5.6	331.9	319.0-358.0	6.5	173.6	154.2-196.8	12.1
Nov.	10	274.0	249.3-304.0	14.7	336.7	320.0-360.5	11.9	164.9	124.1-202.5	15.2
Dec.	10	285.0	265.0-300.0	10.5	345.5	336.8-367.0	6.8	185.4	132.6-198.7	16.3
	200	283.2[1]	337.0-325.0	0.68[2]	341.5[1]	314.3-374.0	0.76[2]	180.7[1]	122.9-256.7	1.0[2]

[1]Average value. [2]Standard deviation.

TABLE X

MEAN MONTHLY VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NORMAL ADULT COWS

(Expressed as mg. per 100 ml.)

Month	No. of Detn.	Blood	Range	M.D.	Plasma	Range	M.D.	Cell	Range	M.D.
Jan.	10	52.2	45.0-61.0	4.7	24.6	23.1-27.0	1.0	104.8	89.4-115.6	8.3
Feb.	10	54.8	40.6-69.2	8.5	25.4	20.2-29.5	1.6	110.5	103.3-125.0	10.7
March	20	50.7	39.5-62.0	4.6	21.3	18.9-28.1	1.1	101.8	70.6-144.5	14.2
April	20	45.5	41.8-61.0	3.4	21.0	18.8-24.1	1.2	102.9	88.0-131.7	10.3
May	20	52.1	36.5-79.0	8.6	19.9	13.3-28.4	2.0	100.2	78.3-121.4	10.9
June	20	49.7	41.5-75.8	5.1	19.7	14.3-25.4	2.1	103.1	86.3-120.9	7.4
July	30	50.0	46.3-80.3	5.8	21.6	15.2-25.8	1.8	102.2	92.4-138.2	4.9
Aug.	20	50.6	39.1-72.5	5.7	22.2	16.2-26.3	1.7	100.2	76.1-129.8	7.2
Sept.	20	51.3	42.3-65.0	4.6	25.2	14.9-31.0	2.2	104.0	77.5-132.9	13.0
Oct.	10	55.7	39.0-68.0	8.2	23.1	20.8-25.7	1.3	136.8	126.9-144.6	6.3
Nov.	10	61.0	44.8-74.5	9.4	23.2	18.5-25.9	1.9	117.8	90.1-125.8	15.2
Dec.	10	57.4	47.2-70.0	6.8	24.5	19.3-30.7	1.4	122.6	100.0-135.3	10.5
	200	51.3[1]	36.5-80.3	0.42[2]	22.2[1]	13.3-31.0	0.12[2]	106.2[1]	70.6-144.6	0.68[2]

[1] Average value. [2] Standard deviation.

TABLE XI

MEAN MONTHLY RATIOS OF SODIUM AND POTASSIUM IN BLOOD OF NORMAL ADULT COWS[1]

	Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na/ cell Na	Plasma K/ cell K
	5.6	14.5	1.8	1.9	0.23
	5.3	13.7	1.6	1.9	0.23
	5.6	16.0	1.8	1.9	0.21
	6.2	16.1	1.7	1.9	0.20
	5.4	17.2	1.7	2.0	0.20
	5.7	17.2	1.6	2.0	0.19
	5.7	16.0	1.9	1.8	0.21
	5.5	15.5	1.8	1.9	0.22
	5.7	13.4	1.9	1.7	0.24
	5.0	14.4	1.3	1.9	0.17
	4.5	14.5	1.4	2.0	0.20
	5.0	14.1	1.5	1.9	0.20
Av.[2]	5.5	15.4	1.7	1.9	0.21

[1] Calculated from the data presented in Tables IX and X.

[2] Average for the 200 samples.

plasma and cells is also given. These ratios are based on the mean values reported in Tables IX and X. The variations from month to month in these ratios are very small, with the exception of sodium to potassium in plasma. Table XII shows the seasonal variations for sodium. There is very little difference for the mean sodium values during the various seasons. When the values for fall and winter are compared with those for spring and summer slight increases are noted in blood and cells. Increases of two and four percent are noted in blood and cells, respectively. These increases are rather small and it seems doubtful that they are significant. The slight increases during winter are in agreement with Hamersma (78). No change is observed in plasma sodium.

Potassium showed slightly larger seasonal variations than sodium (Table XIII). When the fall and winter values are compared with those for spring and summer, 10 percent increases are noted in blood, plasma, and cells. Hamersma stated that potassium decreased during winter, but these data indicate that potassium increased during winter.

Ratios of Sodium and Potassium in Blood of Normal Adult Dairy Cows

Table XIV presents seasonal ratios calculated for sodium and potassium. These ratios seem to be very constant during the various seasons. The ratios of plasma sodium to cell sodium and plasma potassium to cell potassium are remarkably constant. The ratios of sodium to potassium in blood, plasma, and cells tend to increase slightly during spring and summer. This is to be expected, since potassium showed a larger increase than sodium during the winter months.

It is postulated that the mean values for sodium and potassium in whole blood, plasma, and cells of normal adult animals reported in Tables

TABLE XII

INFLUENCE OF SEASON ON MEAN VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NORMAL ADULT COWS[1]

(Expressed as mg. per 100 ml.)

Season	No. of Detn.	Blood	Plasma	Cell
Fall	40	284.7	335.7	184.8
Winter	30	289.1	349.9	185.9
Spring	60	280.8	339.9	173.3
Summer	70	281.7	342.6	182.4
Fall & winter	70	286.6	341.8	185.3
Spring & summer	130	281.3	341.4	178.2

TABLE XIII

INFLUENCE OF SEASON ON MEAN VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NORMAL ADULT COWS[1]

(Expressed as mg. per 100 ml.)

Season	No. of Detn.	Blood	Plasma	Cell
Fall	40	54.8	24.2	115.7
Winter	30	54.8	24.8	113.0
Spring	60	49.4	20.7	101.6
Summer	70	50.1	21.2	101.3
Fall & winter	70	54.8	24.5	114.5
Spring & summer	130	49.8	21.0	101.4

[1]Calculated from the data presented in Tables IX and X.

TABLE XIV

INFLUENCE OF SEASON ON RATIOS OF SODIUM AND POTASSIUM IN BLOOD OF NORMAL ADULT COWS[1]

Season	Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na/ Cell Na	Plasma K/ Cell K
Fall	5.2	13.9	1.6	1.8	0.21
Winter	5.3	14.1	1.6	1.9	0.22
Spring	5.7	16.4	1.7	2.0	0.20
Summer	5.6	16.2	1.8	1.9	0.21
Fall & winter	5.2	14.0	1.6	1.8	0.21
Spring & summer	5.6	16.3	1.8	1.9	0.21

[1] Calculated from the data presented in Tables XII and XIII.

IX and X are more reliable than the mean values from the literature reported in Tables II and III. Two hundred samples were averaged in this study while the largest number reported in the literature is 100 samples. In other studies the standard deviation was not reported, which makes it difficult to estimate the reliability of these values. Most of the reports gave larger ranges than those reported in Tables IX and X. For these reasons it is felt that the mean values reported in this study are more reliable than the values summarized in Tables II and III.

It is interesting to note that bovine red blood cells contain more sodium than potassium. This is unusual since Loeb (2) states that sodium and potassium are biological antagonists and that potassium predominates over sodium in cellular material. Human red blood cells contain very little sodium. This is interesting when one considers that human diets contain a higher percentage of sodium than bovine diets. Cows usually have free access to salt but this is believed to be luxury consumption, since DuToit et al. (77) reported that sodium and potassium in the blood of cattle were not affected by low sodium rations.

Sodium and Potassium Content in Blood of Identical Twins

Table XV summarizes the rations given to the identical twin animals. These rations were adequate from a nutritional standpoint. T-1 and T-2, T-3 and T-4, T-7 and T-8, etc. are the numbers used to identify the identical twin animals. Three sets of twins received identical rations. They were T-3 and T-4, T-11 and T-12, and T-13 and T-14.

Tables XVI and XVII present the data obtained for sodium and potassium in blood, plasma, and cells of identical twin animals taken at

TABLE XV

RATIONS OF THE IDENTICAL TWIN ANIMALS[1]

Animal No.	Ration
T-1	First 3 weeks, grass silage and corn; second 3 weeks, hay and 50 g. calcium phosphate.
T-2	First 3 weeks, grass silage and hay; second 3 weeks, hay, corn silage, and 50 g. calcium phosphate.
T-3	First 3 weeks, corn silage and hay; second 3 weeks, pasture.
T-4	First 3 weeks, corn silage and hay; second 3 weeks, pasture.
T-7	First 2 weeks, corn silage and hay; next 3 weeks hay and gruel.
T-8	Hay.
T-9	Hay.
T-10	Grass silage.
T-11	Hay.
T-12	Hay.
T-13	Hay and corn.
T-14	Hay and corn.
T-17	Corn silage, 50 g. calcium phosphate, 10 g. cobalt.
T-18	Hay, 50 g. dicalcium phosphate, 10 g. cobalt.
T-19	Pasture.
T-20	Hay and corn silage.
T-21	Hay.
T-22	Hay and corn silage.
T-23	Pasture.
T-24	Hay.

[1]All animals, except those on pasture, received 50 g. sodium chloride per day.

TABLE XVI

A COMPARISON OF SODIUM IN WHOLE BLOOD, PLASMA AND CELLS OF IDENTICAL TWINS[1]

(Expressed as mg. per 100 ml.)

	Blood	Plasma	Cell	Blood	Plasma	Cell
		T-1			T-2	
	279.1	336.0	159.4	275.0	339.0	156.0
	283.0	326.5	186.1	282.3	331.0	200.8
	276.5	319.5	177.6	289.0	337.0	175.8
	281.5	336.8	133.1	294.0	334.0	200.7
	293.0	326.8	227.4	288.0	320.5	204.3
	286.8	331.0	192.8	286.0	328.3	187.3
Av.	283.4	329.4	187.8	285.7	331.5	187.5
		T-3			T-4	
	297.5	345.5	210.1	281.0	338.5	200.0
	283.5	332.0	195.5	282.4	336.0	179.1
	280.5	324.0	196.8	280.5	330.0	192.5
	269.5	332.5	164.5	268.5	328.0	173.5
	332.5	372.5	264.3	329.0	372.8	255.7
	283.5	327.5	200.0	287.0	329.5	206.9
Av.	291.1	339.0	205.2	286.6	339.1	201.3
		T-7			T-8	
	288.5	356.5	165.1	277.5	345.5	156.7
	273.5	332.5	169.5	273.5	337.5	164.6
	289.5	355.0	180.3	290.0	341.3	194.6
	286.0	330.5	213.4	292.0	328.0	220.6
	286.8	337.5	192.6	286.8	337.5	192.6
Av.	284.9	342.4	184.2	283.9	338.0	185.6
		T-9			T-10	
	278.5	343.0	150.4	277.5	344.5	153.1
	270.5	330.5	148.8	273.5	330.5	172.2
	273.5	331.0	154.2	267.0	329.0	157.7
Av.	274.2	334.9	151.1	272.3	334.7	161.0

TABLE XVI CONCLUDED

	Blood	Plasma	Cell	Blood	Plasma	Cell
		T-11			T-12	
	267.0	340.0	174.1	261.0	343.5	167.9
	254.0	341.5	159.2	261.5	322.0	183.0
Av.	260.5	340.8	166.7	261.3	332.8	175.5
		T-13			T-14	
	276.0	337.0	176.6	272.0	324.0	192.0
	276.0	334.0	187.1	286.0	335.5	200.0
Av.	276.0	335.5	181.9	279.0	329.8	196.0
		T-17			T-18	
	278.0	323.0	196.3	272.5	323.0	174.4
	331.5	371.5	257.1	325.0	370.5	256.8
	280.3	324.0	195.6	281.0	329.0	198.0
Av.	296.6	339.5	216.3	292.8	340.8	209.7
		T-19			T-20	
	284.0	344.0	194.0	280.5	348.0	179.3
	287.5	336.0	191.3	283.0	253.0	167.0
	275.0	341.0	205.3	280.0	345.0	190.2
Av.	282.0	340.3	196.9	281.2	348.7	178.8
		T-21			T-22	
	287.8	335.0	200.0	277.8	338.0	172.6
	313.5	371.0	221.6	318.0	369.0	227.2
	280.5	329.0	188.4	281.5	328.5	190.3
Av.	293.9	345.0	203.3	292.4	345.2	196.7
		T-23			T-24	
	260.5	348.0	157.4	269.0	342.0	157.0
	276.8	353.8	160.0	253.8	338.0	160.6
	270.0	337.6	168.8	270.0	346.0	151.0
Av.	269.1	346.5	162.1	264.3	342.0	153.6
Gr. Av.[2]	283.1	338.7	186.5	282.0	335.4	186.4

[1] Odd and even numbers are the identical twins, i.e. T-1 and T-2, etc.

[2] Average for all pairs of twins.

TABLE XVII

A COMPARISON OF POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF IDENTICAL TWINS[1]

(Expressed as mg. per 100 ml.)

Blood	Plasma	Cell	Blood	Plasma	Cell
	T-1			T-2	
47.4	20.7	104.1	49.5	22.0	106.0
45.5	18.9	104.8	51.5	21.1	104.4
58.5	21.1	144.6	58.0	22.1	142.6
51.3	21.8	103.6	50.0	23.1	114.3
12.9	22.1	105.3	12.2	24.3	107.1
46.3	21.0	100.0	45.5	17.5	110.7
Av. 43.7	20.9	110.4	43.3	21.7	114.2
	T-3			T-4	
46.9	21.1	95.9	53.5	22.0	97.8
50.0	18.8	106.8	56.5	20.4	104.4
58.0	21.8	127.8	59.0	20.8	126.9
48.3	14.9	109.2	52.0	17.3	107.5
51.5	18.3	108.1	56.3	24.6	110.3
48.0	18.8	103.5	51.8	15.2	102.4
Av. 50.5	19.0	108.6	54.9	20.1	108.2
	T-7			T-8	
50.0	20.1	109.3	62.0	20.1	103.1
52.0	20.4	104.8	51.5	21.0	104.4
65.5	23.8	139.0	68.0	25.7	140.0
56.5	20.8	116.0	52.0	18.9	113.4
57.5	25.8	109.2	52.3	21.3	113.7
48.3	18.6	103.4	46.8	16.2	103.7
Av. 55.0	21.6	113.6	55.4	20.6	113.1
	T-9			T-10	
62.0	20.5	144.5	62.0	21.8	136.6
61.5	21.4	143.0	61.0	21.2	131.7
79.0	23.7	193.0	80.0	23.6	179.0
Av. 67.5	21.9	160.0	67.7	22.2	149.1

TABLE XVII CONCLUDED

Blood	Plasma	Cell	Blood	Plasma	Cell
	T-11			T-12	
53.0	21.8	92.7	55.0	21.3	93.0
59.0	21.2	100.0	57.0	22.0	102.5
Av. 56.0	21.5	96.4	56.0	21.7	97.8
	T-13			T-14	
46.9	20.1	90.5	46.7	20.8	86.3
50.0	21.4	93.9	47.1	19.0	95.9
Av. 48.5	20.8	92.2	46.9	19.9	91.1
	T-17			T-18	
45.5	23.1	89.6	46.8	19.8	99.1
51.0	23.9	100.0	51.0	21.6	93.8
47.5	22.8	95.6	49.3	24.0	92.4
Av. 48.0	23.3	95.1	49.0	21.8	95.1
	T-19			T-20	
56.0	20.4	109.5	57.0	22.2	109.3
49.0	23.0	100.6	53.0	21.8	103.9
51.3	19.9	102.6	56.3	20.2	106.2
Av. 52.1	21.1	104.2	55.4	21.4	106.5
	T-21			T-22	
51.8	19.0	112.6	50.3	19.0	104.7
54.5	24.0	103.1	51.3	22.2	103.1
48.3	23.5	95.4	49.5	22.9	101.2
Av. 51.5	22.2	103.7	50.4	21.4	103.0
	T-23			T-24	
73.3	22.0	133.5	67.0	20.5	138.2
70.0	24.7	142.0	80.0	21.1	146.6
70.8	21.2	145.0	72.5	20.0	154.6
Av. 71.4	22.6	140.2	73.2	20.5	146.5
Gr. Av.[2] 54.8	21.2	113.0	54.6	21.0	113.2

[1] Odd and even numbers are the identical twins, i.e. T-1 and T-2, etc.

[2] Average for all pairs of twins.

weekly intervals. The individual values, the average for the individual animals, and the average for all of the pairs are also given. There were variations from week to week between the individual values for the twins. These variations appeared to be just as large for the animals on the same rations as for those on different rations. The variations between weekly values for the same animal were much smaller than the variations found between two or more different animals. Sodium and potassium in the cells appeared to be more erratic than sodium and potassium in blood and plasma. This is also apparent in Tables IX and X. Occasionally a large drop or rise was shown in a set of twins. It is surprising to note that the drop or rise in one animal was usually accompanied by a similar change in its twin. This rise or drop did not occur in all samples determined at the same time. This is more clearly demonstrated by the potassium values obtained for T-1, T-2, T-3, T-4, T-7, and T-8 (Table XVII). The average for one animal is usually very close to the average for its twin. The differences between the averages for the sets of twins are not as great as the differences between any two animals. The grand averages for all the pairs of twins presented at the end of Tables XVI and XVII are remarkably close. It is evident that the rations fed to these animals did not appear to affect the values for sodium and potassium in whole blood, plasma, and cells. The average values for the twin animals agree with the averages obtained for the normal adult animals (Tables IX and X).

Table XVIII compares the ratios of sodium to potassium in whole blood, plasma, and cells, and also the ratios of plasma sodium to cell sodium and plasma potassium to cell potassium of the identical twins.

TABLE XVIII

A COMPARISON OF THE MEAN RATIOS OF SODIUM AND POTASSIUM IN BLOOD OF IDENTICAL TWINS[1]

Cow No.	Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na /Cell Na	Plasma K /Cell K	Cow No.	Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na /Cell Na	Plasma K /Cell K
T-1	6.5	15.8	1.7	1.8	0.19	T-2	6.6	15.3	1.6	1.8	0.19
T-3	5.8	17.8	1.9	1.7	0.17	T-4	5.2	16.9	1.9	1.7	0.19
T-7	5.2	15.9	1.6	1.9	0.19	T-8	5.1	16.4	1.6	1.8	0.18
T-9	4.1	15.3	0.94	2.2	0.14	T-10	4.0	15.1	1.1	2.1	0.15
T-11	4.7	15.9	1.7	2.0	0.22	T-12	4.7	15.3	1.8	1.9	0.22
T-13	5.7	16.1	2.0	1.8	0.23	T-14	5.9	16.6	2.2	1.7	0.22
T-17	6.2	14.6	2.3	1.6	0.25	T-18	6.0	15.6	2.2	1.6	0.23
T-19	5.4	16.1	1.9	1.7	0.20	T-20	5.1	16.3	1.7	2.0	0.20
T-21	5.7	15.5	2.0	1.7	0.21	T-22	5.8	16.1	1.9	1.8	0.21
T-23	3.8	15.3	1.2	2.1	0.16	T-24	3.6	16.7	1.0	2.2	0.14
Av.	5.4	16.0	1.7	1.8	0.19		5.3	16.1	1.7	1.8	0.18

[1] Calculated from the data presented in Tables XVI and XVII.

The ratios for one animal agree quite well with the ratios for its twin. The largest discrepancies appear to be in the sodium to potassium ratios in plasma. However, these discrepancies are no larger percentage wise than the others.

The results reported on Tables XVI and XVII, which summarize the values for identical twins are remarkable. The mean values for sodium and potassium are for all practical purposes the same. This work indicates that identical twins are excellent subjects for experimentation. One twin could be used as a control and the other as the experimental animal. The estrus cycle in these twins is at about the same time, which might possibly explain the large increases or decreases that were noted in Table XVII..

Sodium and Potassium Content in Blood of Young Calves

Tables XIX and XX present the mean values obtained for sodium and potassium in whole blood, plasma, and cells of 12 calves from birth to 12 weeks of age. Whole blood sodium and cell sodium are low at birth, but show a general increase to the normal adult level at about 10 to 12 weeks of age. The increases for whole blood sodium and cell sodium are presented graphically in Figures 5 and 6, respectively. The increase for whole blood sodium from the lowest value at two weeks of age to the normal value at 12 weeks is 21 percent. The increase in cell sodium from the lowest point at two weeks to the normal value is 300 percent. Plasma sodium did not show any significant increase or decrease during the period studied. Whole blood, plasma, and cell potassium were high at birth, but a general downward progression to a normal adult value

TABLE XIX

MEAN VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF TWELVE YOUNG CALVES

(Expressed as mg. per 100 ml.)

Age	Blood	Range	S.D.	Plasma	Range	S.D.	Cell	Range	S.D.
0 hr.	230.8	212.3-286.0	5.7	350.8	340.8-380.5	2.8	65.8	24.5-151.6	6.8
72 hr.	242.1	228.5-263.5	2.4	331.9	246.5-370.5	5.6	59.0	30.3- 89.0	4.4
1 wk.	232.6	211.5-257.5	4.0	335.5	305.5-352.3	2.5	57.2	23.7- 91.8	6.3
2 wk.	221.6	122.5-250.3	11.1	333.5	321.0-345.3	2.6	53.2	0.0-111.7	10.0
3 wk.	251.2	238.3-268.5	2.4	342.4	333.0-354.5	2.6	65.5	0.0-120.7	13.0
4 wk.	257.1	251.0-262.6	1.2	338.8	329.5-354.5	3.0	77.1	0.0-148.1	14.1
5 wk.	262.1	241.0-271.5	3.0	340.5	332.0-353.0	2.4	116.7	37.5-165.4	9.8
6 wk.	268.7	229.8-273.0	0.9	332.8	324.0-340.5	1.7	110.1	63.6-147.6	7.1
7 wk.	265.6	264.0-268.0	0.3	324.4	318.5-336.5	1.4	147.0	105.8-180.5	9.2
8 wk.	268.7	257.5-287.5	2.6	331.4	325.5-343.0	1.6	114.9	89.4-159.6	5.6
9 wk.	277.8	267.5-288.0	2.9	328.8	322.5-332.0	1.3	169.0	160.6-177.3	2.3
10 wk.	275.0	261.0-289.0	4.0	329.8	327.0-332.5	0.8	155.0	132.9-177.1	6.3
11 wk.	278.0	263.0-287.0	3.3	341.6	330.8-349.8	1.5	172.3	145.6-196.4	5.1
12 wk.	281.6	273.8-296.0	2.7	335.5	330.8-343.5	1.6	184.9	174.4-203.8	2.0

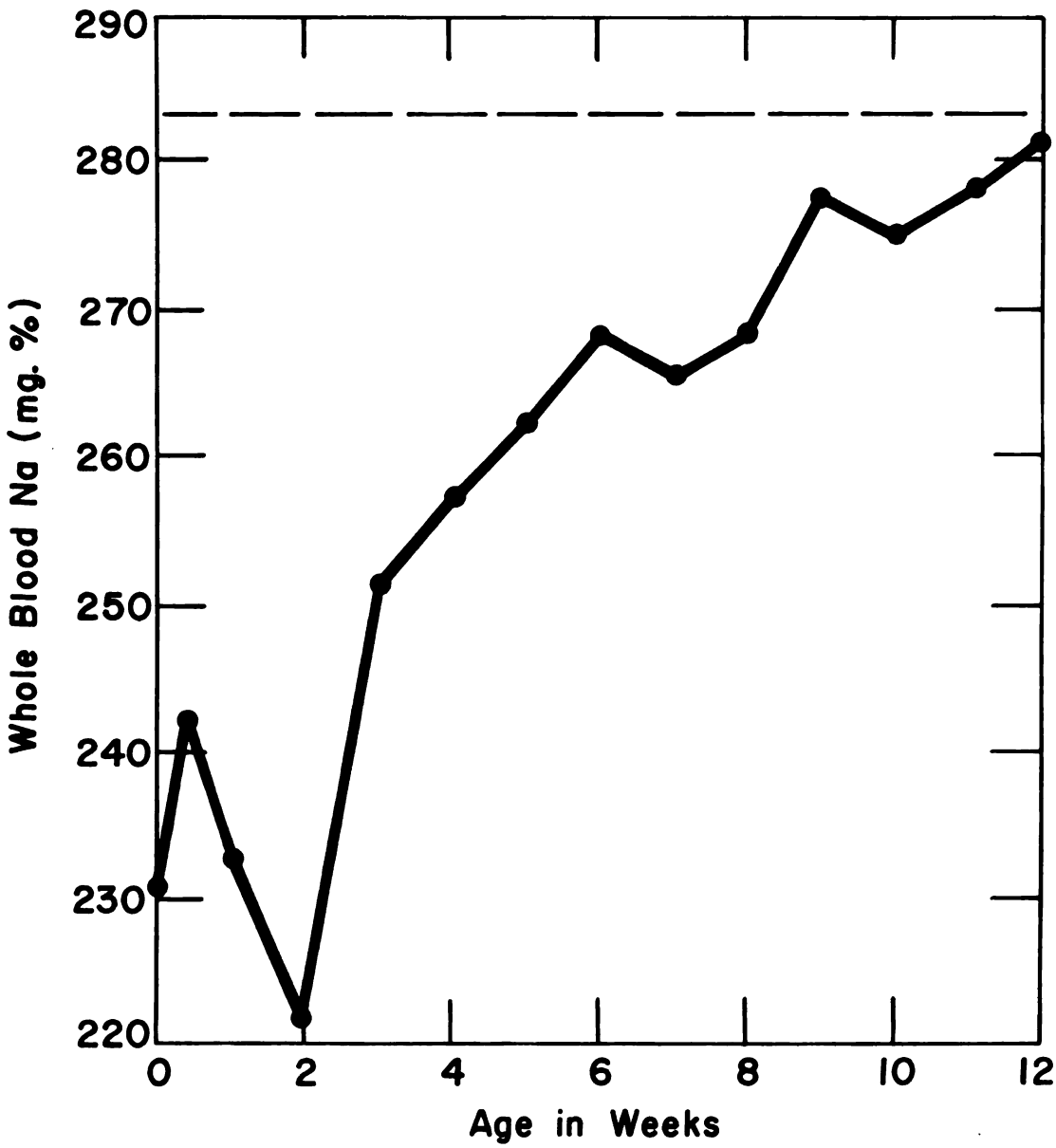

Figure 5. Concentrations of sodium in the whole blood of calves from birth to twelve weeks of age. Dashed line is the average for adult cows.

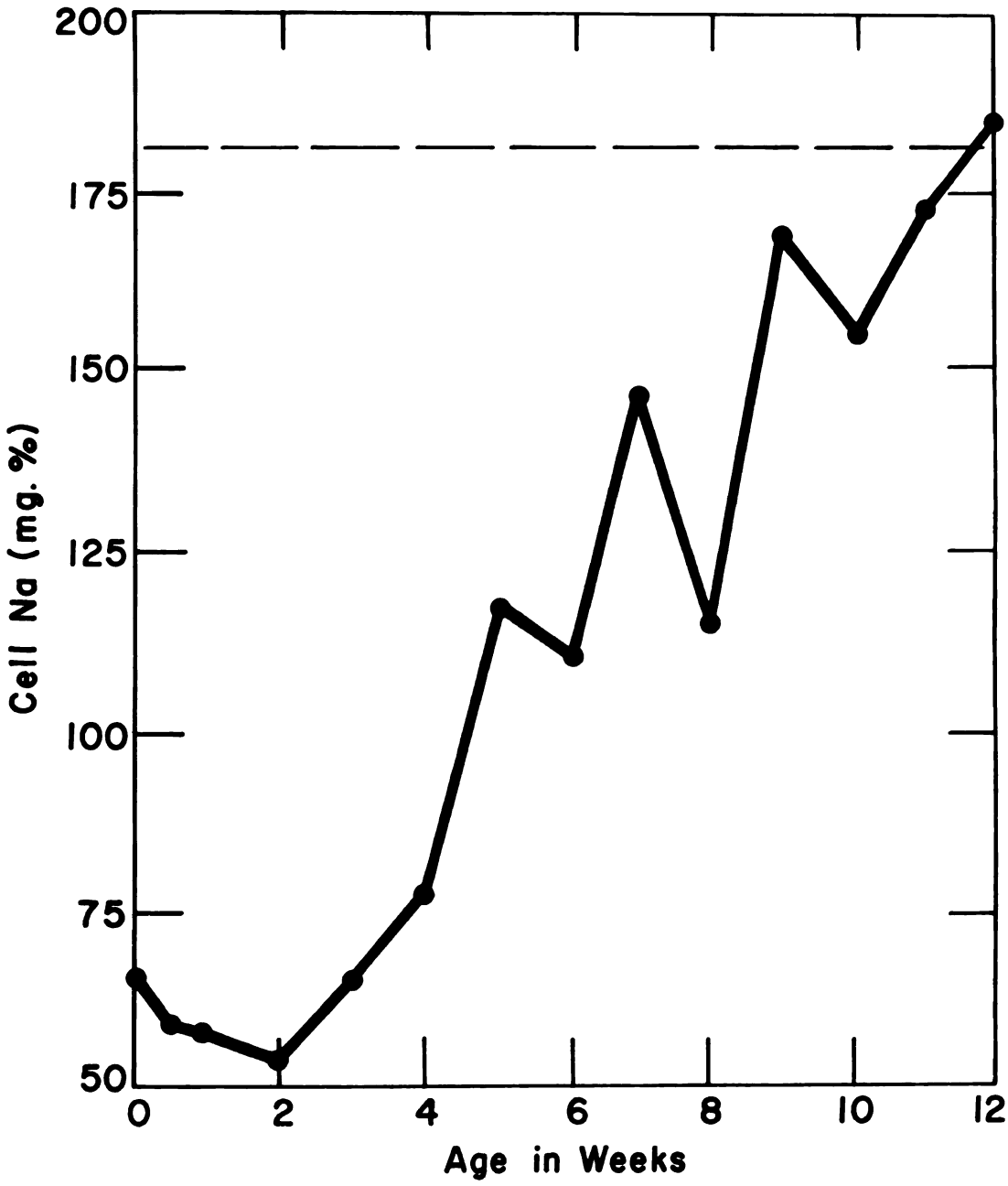

Figure 6. Cell sodium in calves from birth to twelve weeks of age.
Dashed line is the average for adult cows.

TABLE XX

MEAN VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF TWELVE YOUNG CALVES

(Expressed as mg. per 100 ml.)

Age	Blood	Range	S.D.	Plasma	Range	S.D.	Cell	Range	S.D.
0 hr.	174.2	106.0-198.5	6.6	31.5	24.2-39.7	9.0	358.6	177.2-415.3	12.8
72 hr.	146.1	118.0-174.5	3.6	25.9	23.0-31.5	0.6	377.6	312.3-440.0	7.5
1 wk.	147.4	106.5-184.8	5.2	26.3	24.9-29.4	0.34	363.1	306.0-401.8	9.3
2 wk.	124.6	68.3-141.8	6.6	26.8	24.1-29.1	0.37	316.3	157.8-408.3	20.0
3 wk.	117.0	95.0-130.3	5.3	26.3	25.6-27.2	0.20	292.5	239.1-360.4	9.6
4 wk.	110.3	100.3-115.5	1.8	25.5	24.4-27.2	0.30	302.9	252.9-360.4	10.9
5 wk.	94.5	76.0-106.8	2.6	24.6	22.5-28.1	0.57	224.5	179.4-259.4	8.6
6 wk.	89.7	74.5-102.5	2.8	24.9	23.9-25.5	0.17	249.5	200.4-326.2	14.6
7 wk.	92.0	89.0- 94.5	0.57	24.1	22.0-26.5	0.37	228.2	190.6-295.1	9.8
8 wk.	79.8	60.0- 97.5	4.5	24.4	21.8-26.0	0.42	211.0	156.6-292.1	14.4
9 wk.	67.5	53.0- 82.0	4.1	23.9	23.4-24.4	0.14	158.4	123.0-193.8	10.1
10 wk.	60.8	37.5- 84.0	6.6	22.6	22.0-23.2	0.16	139.8	77.5-202.0	17.8
11 wk.	57.4	39.8- 81.0	5.2	22.0	21.0-24.1	0.17	112.3	71.3-187.6	12.1
12 wk.	55.7	49.2- 60.0	1.2	23.4	20.1-27.1	0.71	106.8	92.1-116.1	8.0

was evident. These changes are presented graphically on Figures 7, 8, and 9. Whole blood potassium at birth was found to be about three times the normal adult value. Plasma potassium was about one-third higher, whereas cell potassium was about three and one-half times normal. The standard deviations for whole blood and cell sodium for young calves are quite large. The standard deviations are based on a small number of determinations.

Table XXI presents the mean ratios of sodium to potassium in whole blood, plasma, and cells of the young calves. It also shows the ratios of plasma sodium to cell sodium and plasma potassium to cell potassium. These ratios are presented graphically in Figures 10, 11, 12, and 13. The ratio of sodium to potassium is not presented graphically because no marked change was found from birth to 12 weeks of age. All of the ratios increased with age and approached the normal value at 12 weeks of age, except plasma sodium to cell sodium. Plasma sodium to cell sodium decreased to a normal ratio at 12 weeks of age. The ratio in whole blood at birth was one-fourth the normal ratio. The ratio in cells at birth was one-tenth the normal ratio. The ratio of sodium in plasma and cells at birth was three times the normal ratio. The potassium ratio in plasma and cells at birth is one-half the normal ratio.

Table XXII presents the total milliequivalents per liter of sodium and potassium in whole blood, plasma, and cells of the young calves. The totals for normal adult animals are included for comparison. Totals in blood and plasma agree quite well with the totals for normal adult animals. The cell total seems to show discrepancies. The discrepancies noted in cells might be accounted for by the fact that they are calculated

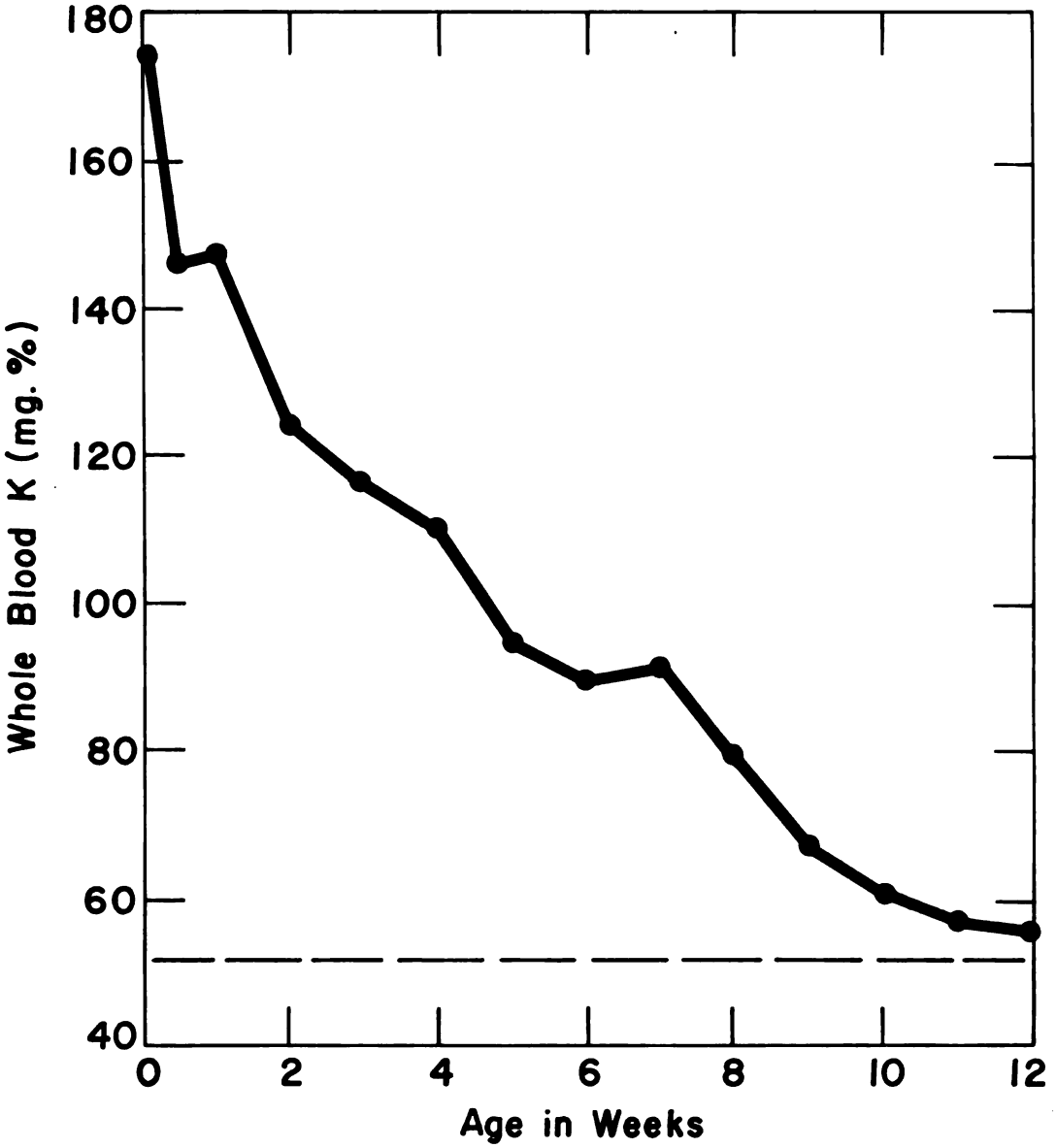

Figure 7. Whole blood potassium in calves from birth to twelve weeks of age.
Dashed line is the average for adult cows.

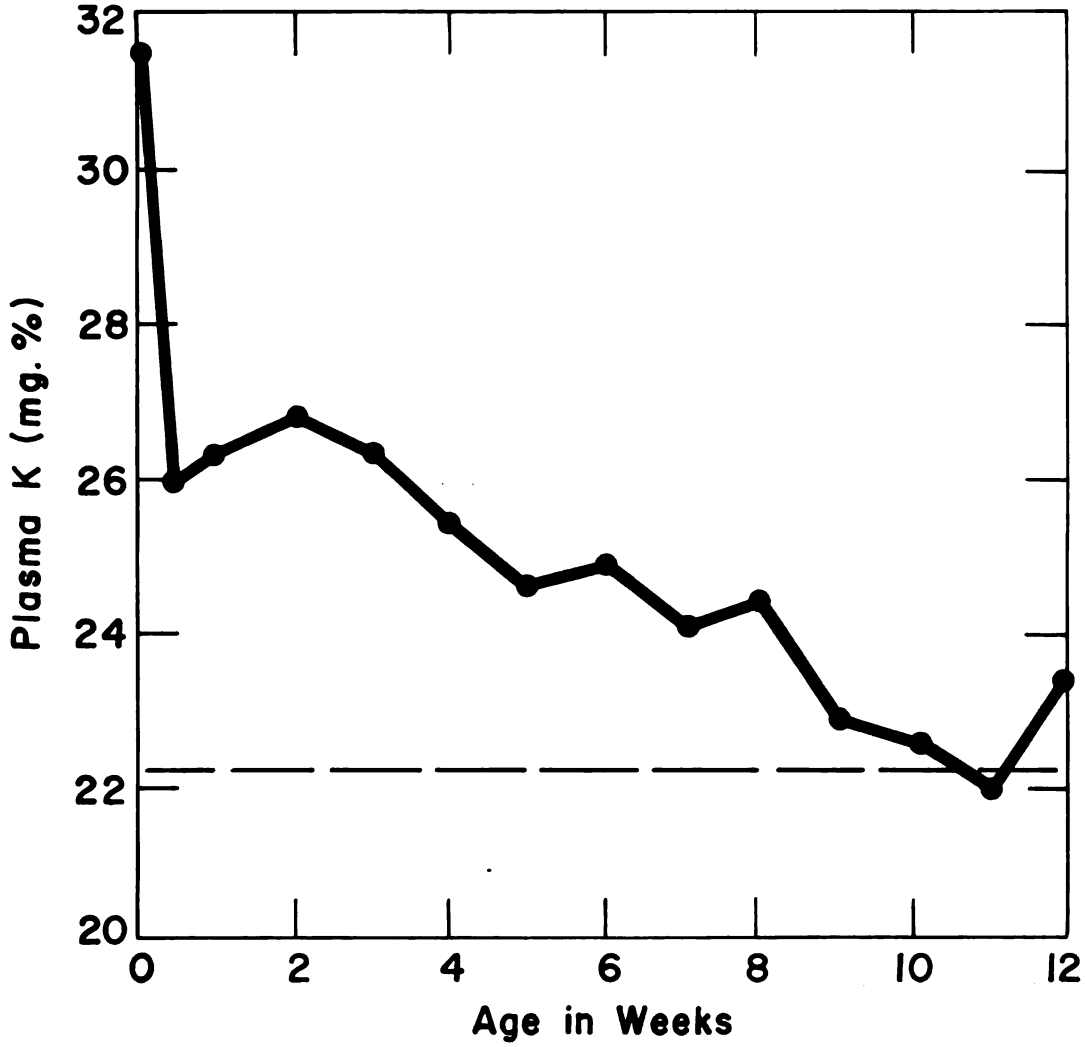

Figure 8. Plasma potassium in calves from birth to twelve weeks of age.
Dashed line is the average for adult cows.

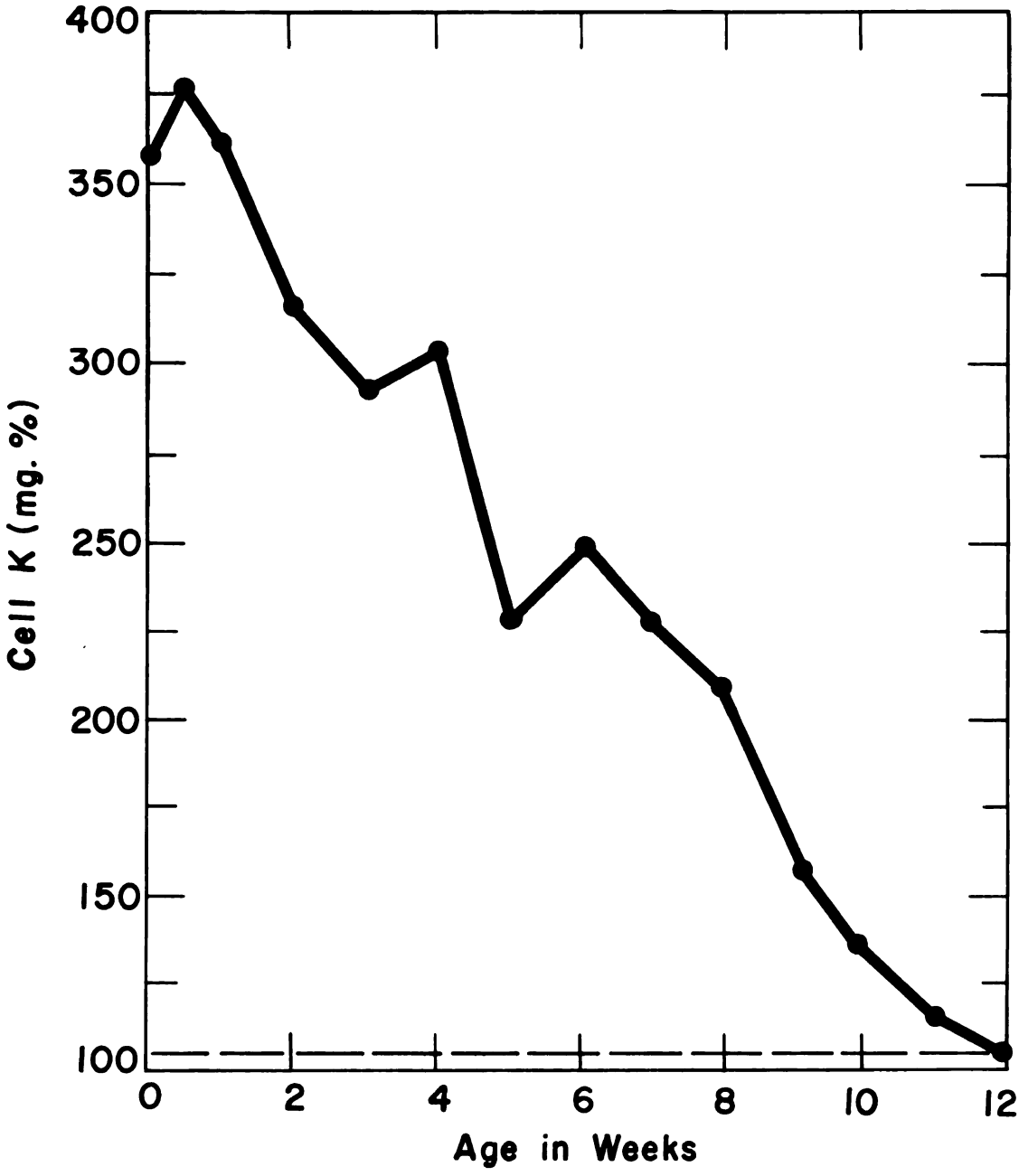

Figure 9. Cell potassium in calves from birth to twelve weeks of age.
Dashed line is the average for adult cows.

TABLE XXI

RATIOS OF SODIUM AND POTASSIUM
IN BLOOD OF TWELVE YOUNG CALVES[1]

Age	Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na /Cell Na	Plasma K /Cell K
0 hr.	1.3	11.1	0.18	5.3	0.09
72 hr.	1.7	12.8	0.15	5.6	0.07
1 wk.	1.6	12.8	0.16	5.9	0.07
2 wk.	1.8	12.4	0.17	6.3	0.08
3 wk.	2.1	13.0	0.22	5.2	0.09
4 wk.	2.3	13.3	0.25	4.4	0.08
5 wk.	2.8	9.8	0.50	2.9	0.11
6 wk.	3.0	13.4	0.70	3.0	0.10
7 wk.	2.9	13.5	0.60	2.2	0.11
8 wk.	3.4	13.6	0.50	2.9	0.12
9 wk.	4.1	13.8	1.10	1.9	0.15
10 wk.	4.5	14.6	1.10	2.1	0.16
11 wk.	4.8	15.5	1.50	2.0	0.20
12 wk.	5.1	14.3	1.70	1.8	0.22

[1]Calculated from the data presented in Tables XIX and XX.

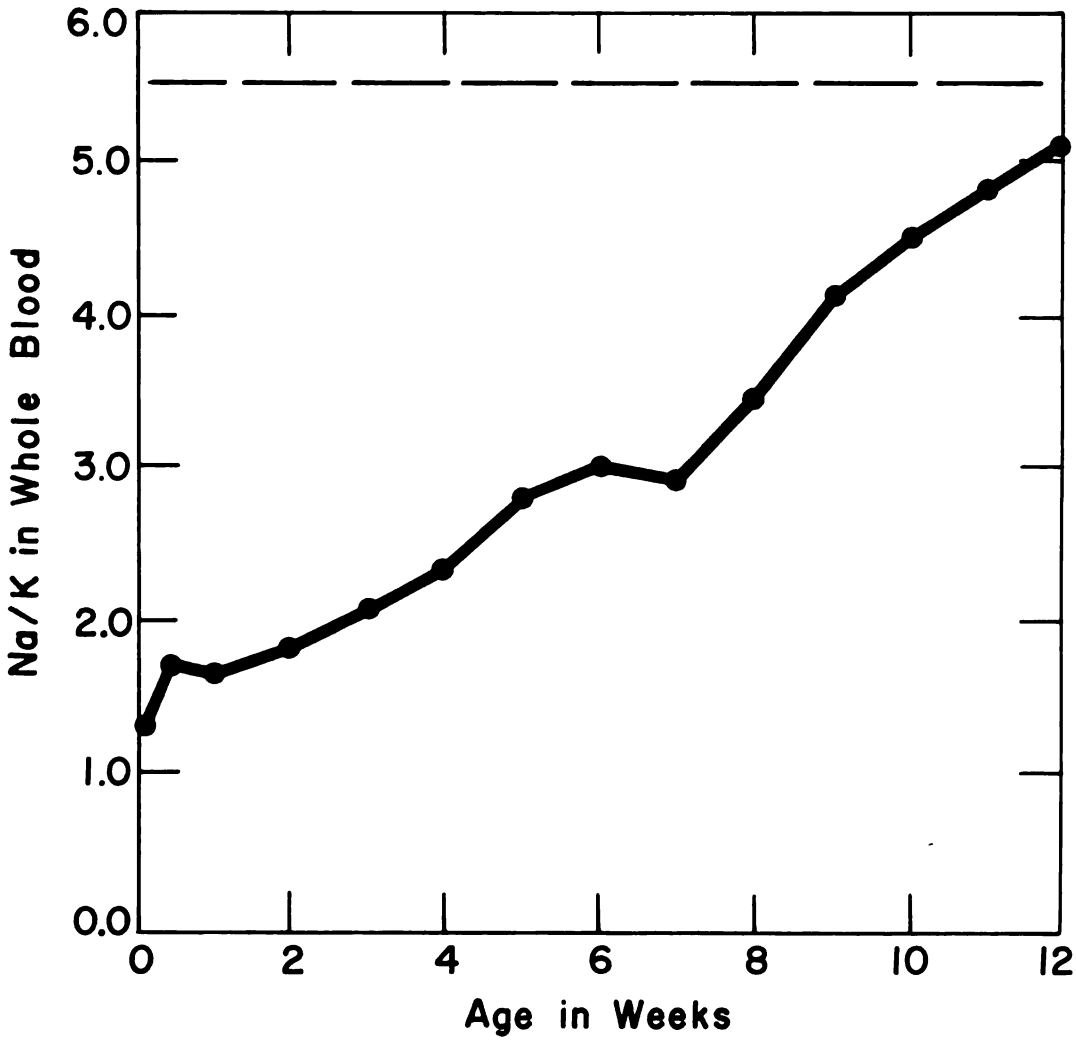

Figure 10. Ratio of sodium to potassium in whole blood of calves from birth to twelve weeks of age. Dashed line is the average for adult cows.

TABLE XXII

THE SUM OF SODIUM AND POTASSIUM IN WHOLE BLOOD, PLASMA AND CELLS OF TWELVE YOUNG CALVES[1]

(Expressed as meq. per liter)

Age	Blood	Plasma	Cells
0 hr.	145.0	154.2	120.3
72 hrs.	142.7	160.6	122.3
1 wk.	138.8	150.9	117.8
2 wk.	128.3	152.6	104.0
3 wk.	139.1	151.9	103.3
4 wk.	140.0	155.6	111.0
5 wk.	138.2	153.8	108.1
6 wk.	139.7	154.3	111.7
7 wk.	139.0	151.1	122.3
8 wk.	137.2	147.2	104.0
9 wk.	138.1	150.3	114.0
10 wk.	135.2	149.1	103.2
11 wk.	135.6	149.2	103.6
12 wk.	136.6	155.1	107.7
Normal Adults[2]	136.2	151.9	105.8

[1] Calculated from the data presented in Tables XIX and XX.

[2] Calculated from the data presented in Tables IX and X.

values and, therefore, are not as reliable as the determined values. The data presented in Table XXII indicate that the total milliequivalents of sodium and potassium do not change although the data in Tables XIX and XX indicate that potassium is high and sodium is low at birth. It appears from the results reported that potassium replaces sodium at birth and that sodium gradually replaces potassium until a normal balance is attained at approximately 12 weeks of age. None of the data obtained for the young calves gave a steady progression up or down. If a larger number of calves had been available, some of the difficulty might have been eliminated. Hay was available to the calves and since it is high in potassium, it might have contributed to the fluctuation, depending on the amount consumed.

It is postulated that there must be a high demand for potassium in the development of a newborn calf, since the potassium values in whole blood, plasma, and cells are significantly higher than the values for adult animals. This is supported by the fact that colostrum, which is higher in potassium than normal mature milk, is the normal nutrient during the first few days of life. Potassium is a constituent of the enzyme system involved in the formation of pyruvate from phosphoenol pyruvate in carbohydrate metabolism. Flock et al. (90) showed that continued intravenous administration of glucose lowered the serum potassium concentration. Since colostrum and milk are good sources of carbohydrate, Flock's work might explain, in part, the apparent need for high potassium concentrations in newborn calves. Gillis (91) reported that inadequate potassium intake in chicks and young rats resulted in lower growth rates. The diets that contained inadequate amounts of

potassium resulted in lowered bone calcification due to an abnormal phosphorous metabolism. It is postulated that the high levels of potassium in whole blood, plasma, and cells act as a reserve for the animal. This reserve seems to be essential since milk, which is the normal nutrient, is a poor source of potassium. The animals had access to hay, which is a good source of potassium, but they did not consume large amounts. It is also postulated that potassium is metabolized and excreted at a more rapid rate than it is ingested which might account for the gradual decrease in the blood. The studies on newborn calves are important in that the normal values for the calves are not the same as the normal values for adult cows. This could be important from a clinical standpoint.

Sodium and Potassium Content in Blood of Cows During the Parturition Period

Tables XXIII and XXIV present the mean values for sodium and potassium in whole blood, plasma, and cells of six cows before, during, and after parturition. The values obtained three weeks after parturition agree with the mean values for normal animals (Tables IX and X). The values obtained for sodium in whole blood, plasma, and cells seem to be slightly higher before parturition than the values after parturition. The values for potassium do not show any marked change prepartum or postpartum. However, a slight increase was noted during parturition. The samples that were taken shortly before parturition showed some changes in sodium and potassium, but the trend can not be regarded as conclusive. The data obtained at the time of parturition are in

TABLE XXIII

MEAN VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF SIX COWS DURING THE PREPARTUM, PARTURITION, AND POSTPARTUM PERIODS

(Expressed in mg. per 100 ml.)

Time	Blood	Range	S.D.	Plasma	Range	S.D.	Cell	Range	S.D.
3 wks. prepartum	294.4	287.8-301.0	1.7	350.4	343.3-360.5	2.6	193.8	177.1-207.9	3.7
2 wks. prepartum	290.0	280.3-305.6	1.9	348.7	339.0-371.0	3.0	188.1	172.3-200.1	3.0
1 wk. prepartum	295.5	288.3-304.0	2.1	347.5	339.5-356.8	2.2	205.5	191.9-215.3	2.7
3 days prepartum[1]	282.5	—	—	335.8	—	—	202.5	—	—
4 hrs. prepartum[1]	287.3	—	—	350.0	—	—	180.5	—	—
0 hr. parturition	287.5	278.8-302.5	2.6	349.6	337.5-374.0	4.5	201.7	169.5-215.2	8.7
72 hr. postpartum	284.3	276.5-296.5	2.1	361.8	332.5-438.0	10.5	164.8	37.9-222.7	17.7
1 wk. postpartum	286.7	279.0-294.8	3.0	337.8	327.0-347.3	3.8	203.5	198.4-207.0	1.0
2 wks. postpartum	284.6	272.3-291.0	2.0	339.6	330.0-345.2	2.1	186.3	172.4-193.5	1.1
3 wks. postpartum	282.3	274.5-290.0	1.8	343.2	334.1-347.3	1.6	182.4	174.6-188.8	0.8

[1]Single sample, same cow.

TABLE XXIV

MEAN VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF SIX COWS DURING THE PREPARTUM, PARTURITION, AND POSTPARTUM PERIODS

(Expressed in mg. per 100 ml.)

Time	Blood	Range	S.D.	Plasma	Range	S.D.	Cell	Range	S.D.
3 wks. prepartum	52.0	49.0-54.0	0.53	22.0	20.4-24.0	0.39	105.2	98.9-110.2	2.5
2 wks. prepartum	51.6	48.8-53.3	0.56	21.9	20.6-23.9	0.40	104.1	97.2-111.8	2.7
1 wk. prepartum	47.8	44.3-51.5	1.3	19.2	16.6-20.3	0.52	97.5	86.9-100.5	3.6
3 days prepartum[1]	60.3	--	--	18.7	--	--	122.8	--	--
4 hrs. prepartum[1]	49.8	--	--	18.7	--	--	102.7	--	--
0 hr. parturition	63.6	45.5-111.5	22.0	23.5	19.3-28.2	0.92	118.0	75.9-207.3	11.8
72 hr. postpartum	49.0	40.3-55.8	1.7	18.7	16.6-22.6	0.70	95.7	79.2-109.3	3.0
1 wk. postpartum	46.6	41.8-51.0	0.76	19.9	18.4-21.4	0.36	89.9	80.5-102.4	2.5
2 wks. postpartum	48.5	42.6-53.0	0.7	20.6	18.8-22.5	0.40	95.0	84.3-106.7	2.8
3 wks. postpartum	50.0	44.8-58.7	1.2	21.0	18.3-23.0	0.52	102.0	87.6-110.1	2.6

[1]Single sample, same cow.

agreement with the results reported by Sellers *et al.* (71, 81) and Ward *et al.* (72, 82).

Sodium and Potassium Content in Blood of Cows with Endematous Udders

Table XXV presents the individual sodium and potassium values in whole blood, plasma, and cells for the two cows with endematous udders. The variations in these cows from week to week tend to be larger than the weekly variations of normal animals such as the twins. The mean sodium whole blood and plasma values for Cow No. 1 are higher than the mean values presented in Table IX, whereas the cell sodium value is lower. Whole blood and cells contain more potassium, while the plasma contains less than the mean normal amounts (Table X). Cow No. 2 had a low whole blood and cell sodium value while plasma sodium was normal as compared to the values presented in Table IX. This animal had a low plasma potassium value and high values for blood and cell potassium as compared to normal (Table X). These values can not be considered as conclusive since only two animals were available The only large variation is in the cell values. Cell potassium is about 30 percent higher and cell sodium is about 20 percent lower. The plasma sodium value for the first cow of 800 mg. percent is very doubtful. It seems possible that it is an artifact or that contamination of the sample occurred.

Table XXVI presents the ratios of sodium to potassium in whole blood, plasma, and cells of the two cows with endematous udders. The ratios do not agree very well with the ratios for normal adult animals (Table XI). The ratios of the first animal that involve the plasma and cell sodium are doubtful because of the influence of the doubtful

TABLE XXV

VALUES FOR SODIUM AND POTASSIUM IN BLOOD, PLASMA, AND CELLS OF TWO COWS WITH EDEMATOUS UDDERS

(Expressed in mg. per 100 ml.)

Blood	Plasma	Cells	Blood	Plasma	Cells
	Sodium			Potassium	
		Cow No. 1			
286.2	357.7	153.4	56.5	21.0	122.3
288.5	357.5	151.6	55.5	21.7	122.7
297.5	346.3	165.6	54.6	14.9	161.9
272.5	343.5	114.5	67.4	18.7	175.8
288.8	338.8	189.6	56.5	18.3	132.2
307.0	800.0	0.0	55.0	21.1	134.0
290.0	332.2	191.3	53.3	21.0	128.7
285.0	337.0	184.1	57.0	22.4	124.1
295.0	343.8	188.9	53.0	17.7	129.8
289.0	336.0	184.5	56.5	21.8	133.9
Av. 290.0	389.3	152.3	56.5	19.9	136.5
		Cow No. 2			
276.0	351.7	171.4	65.0	15.8	133.1
278.9	361.0	165.5	66.5	15.4	136.9
273.5	336.5	170.8	62.9	10.7	148.2
192.5	303.5	26.0	95.9	18.1	211.5
267.5	334.0	184.5	69.0	17.3	133.5
275.0	356.0	163.1	68.3	19.7	135.5
273.0	339.3	185.1	68.8	21.0	132.1
278.8	344.0	184.9	68.0	18.7	139.0
Av. 264.4	340.7	156.4	70.5	17.1	146.2

TABLE XXVI

RATIOS OF SODIUM AND POTASSIUM IN BLOOD OF TWO ANIMALS WITH ENDEMATOUS UDDERS[1]

Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na/ Cell N	Plasma K/ Cell K
		Cow No. 1		
5.1	17.0	1.3	2.3	0.17
5.2	16.5	1.2	2.4	0.18
5.4	23.2	1.0	2.1	0.09
4.0	18.4	0.7	3.0	0.11
5.1	18.5	1.4	1.8	0.14
5.6	37.9	0.0	0.0	0.16
5.4	15.8	1.5	1.7	0.16
5.0	15.0	1.5	1.8	0.18
5.6	19.4	1.5	1.8	0.14
5.1	15.4	1.4	1.8	0.16
Av. 5.1	19.6	1.1	2.6	0.15
		Cow No. 2		
4.2	22.3	1.3	2.1	0.12
4.2	23.4	1.2	2.2	0.11
4.3	31.4	1.2	2.0	0.07
2.0	16.8	0.12	11.7	0.09
3.9	19.3	1.4	1.8	0.13
4.0	18.1	1.2	2.2	0.15
4.0	16.2	1.4	1.8	0.16
4.1	18.4	1.3	1.9	0.13
Av. 3.8	19.9	1.1	2.2	0.12

[1] Calculated from the data presented in Table XXV.

value of 800 mg. percent for plasma sodium. However, if this value is disregarded, the ratios of sodium to potassium in plasma and plasma sodium to cell sodium would still be high in the first animal. The cell sodium to cell potassium ratio is low. The ratios of blood sodium to blood potassium and plasma potassium to cell potassium are low in the first animal. The ratios for Cow No. 2 follow the same general pattern as those for Cow No. 1.

Sodium and Potassium Content in Blood of Sterile Cows and Heifers

Table XXVII presents the mean values for sodium in whole blood, plasma, and cells of 13 sterile cows. Table XXVIII presents similar data obtained for nine cows on the same sterility project that eventually conceived. The average value for whole blood sodium of the cows that did not conceive is lower than the average for the cows that did conceive. The mean value for whole blood sodium for all the cows on the sterility project is lower than the mean whole blood sodium value for normal cows (Table IX). No differences were evident in plasma sodium in either group of the sterility project. The mean plasma sodium value for all the animals of the sterility group agrees very well with the mean value for plasma sodium (Table IX). The mean cell sodium value for the animals that did not conceive was 10 percent lower than the mean value for the group that did conceive. The mean values for cell sodium in both groups on the sterility project are lower than the mean value reported in Table IX. Cell sodium was 25 percent lower in the animals that did not conceive and 18 percent lower in the animals that did conceive.

TABLE XXVII

MEAN VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF THIRTEEN STERILE COWS AND HEIFERS USED IN THE STERILITY PROJECT

(Expressed in mg. per 100 ml.)

Blood[1]	Range	M.D.	Plasma[1]	Range	M.D.	Cell[1]	Range	M.D.
245.5	220.0-258.0	10.6	328.8	318.0-340.0	8.5	68.6	39.7-151.4	20.4
260.3	240.3-281.0	11.3	340.5	328.0-356.0	7.0	124.7	117.3-133.1	5.2
262.3	254.0-270.5	9.3	335.8	322.5-349.5	6.4	138.9	128.0-151.8	11.1
267.8	257.0-274.5	7.4	341.9	332.5-356.0	6.3	152.2	128.4-160.0	11.6
270.7	263.0-278.5	5.2	336.8	323.0-349.5	4.9	128.1	106.1-172.3	16.4
271.3	264.3-292.5	9.9	335.0	330.6-352.1	6.2	175.5	168.3-186.3	8.1
279.3	262.0-283.5	7.8	340.5	336.2-345.4	4.1	179.2	164.9-190.7	8.0
264.0	247.9-283.0	8.1	332.8	318.6-345.0	10.1	117.2	95.8-137.5	12.9
273.0	252.4-294.0	10.2	333.5	323.0-352.1	9.8	187.7	146.7-199.9	17.8
238.2	225.6-250.0	7.6	343.4	232.6-361.7	8.9	84.0	71.8- 97.2	5.9
264.0	251.0-273.8	9.0	332.9	311.0-350.0	9.9	189.5	144.3-199.7	20.0
273.8	262.0-281.5	8.1	344.2	334.0-360.0	10.6	166.1	138.9-208.0	24.6
286.8	274.0-296.0	8.6	339.1	334.0-348.0	5.9	187.0	151.5-214.6	23.3
265.9[2]	220.0-296.0	2.4[3]	337.3[2]	311.0-361.7	2.7[3]	146.0[2]	39.7-214.6	5.1[3]

[1] Ten samples per animal.

[2] Mean for the 130 samples.

[3] Standard deviation.

TABLE XXVIII

MEAN VALUES FOR SODIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NINE COWS AND HEIFERS USED IN THE STERILITY PROJECT THAT DID CONCEIVE

(Expressed in mg. per 100 ml.)

Blood[1]	Range	M.D.	Plasma[1]	Range	M.D.	Cell[1]	Range	M.D.
266.8	254.0-279.5	8.7	344.0	335.0-358.0	4.8	127.4	112.4-143.4	12.4
275.5	267.5-289.5	6.3	344.8	338.0-356.5	5.9	126.6	119.9-141.3	9.8
273.0	259.0-287.0	8.3	344.0	331.0-356.0	5.0	112.3	108.7-126.0	6.7
283.0	270.0-296.0	10.0	335.0	324.2-348.9	6.7	182.8	173.5-192.8	5.4
265.3	248.6-271.3	6.3	337.0	322.3-349.6	7.2	146.7	133.8-156.6	11.0
282.9	270.0-289.8	8.6	341.6	335.3-352.0	6.6	203.9	178.6-222.6	16.9
292.0	277.5-303.5	8.3	339.3	334.0-349.0	6.4	215.2	183.7-232.7	21.0
276.5	260.5-283.5	10.6	332.0	319.4-347.6	7.3	157.0	134.2-177.7	15.8
275.3	268.0-282.5	4.8	332.1	321.5-342.8	7.1	196.4	174.0-232.0	23.7
276.7[2]	248.6-303.5	2.4[3]	338.9[2]	319.4-358.0	1.9[3]	163.1[2]	108.7-232.7	4.1[3]
270.3[4]	220.0-296.0[5]	0.57[6]	338.0[4]	232.6-361.7[5]	0.48[6]	153.0[4]	39.7-232.7[5]	0.95[6]

[1] Ten samples per animal.

[2] Mean for the 90 samples.

[3] Standard deviation.

[4] Mean for the 220 samples.

[5] Range for the 220 samples.

[6] Standard deviation for the 220 samples.

Table XXIX presents the mean values for potassium in whole blood, plasma, and cells of 13 animals used in the sterility project that did not conceive. Table XXX presents similar data obtained for nine cows on the same sterility project that eventually conceived. The average value for whole blood potassium in the animals that did not conceive was almost 70 percent higher than the average value for the animals that did conceive. The average value for the animals that did not conceive was about 100 percent higher than the mean value obtained for whole blood potassium (Table X). The mean value for whole blood potassium of the animals that did conceive was about the same as the mean value presented in Table X. Plasma potassium was the same in both groups on the sterility project and compares favorably with the mean value presented in Table X. The mean value for cell potassium was 18 percent higher in the animals that did not conceive than the mean value in the group that did conceive. Cell potassium was 40 percent higher in the group that did not conceive than the mean value for cell potassium presented in Table X. Cell potassium was 20 percent higher in the group that did conceive than the mean value presented in Table X. It is evident from the wide range and large mean deviations that the individual animals varied considerably from month to month. This large individual variation was not evident with other animals, particularly the twins.

Table XXXI presents the ratios in the blood of the animals that did and did not conceive. The mean ratios for the two groups are the same with the exception of sodium to potassium in whole blood. These mean ratios differ considerably on a percentage basis from the mean ratios presented in Table XI.

TABLE XXIX

MEAN VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF THIRTEEN STERILE COWS AND HEIFERS USED IN THE STERILITY PROJECT

(Expressed in mg. per 100 ml.)

Blood[1]	Range	M.D.	Plasma[1]	Range	M.D.	Cell[1]	Range	M.D.
107.1	104.5-113.0	4.9	21.8	20.5-23.2	1.8	252.1	249.2-306.1	25.1
70.3	58.4- 80.5	8.0	23.0	20.0-25.6	2.0	151.7	139.6-178.4	14.0
61.3	45.2- 79.0	8.6	22.1	19.9-23.3	1.6	126.5	119.2-140.7	8.9
60.8	50.0- 73.5	2.8	23.2	21.3-24.5	3.9	119.5	104.2-135.4	13.6
52.3	40.0--60.0	2.1	22.0	18.2-24.4	2.8	120.3	105.5-132.2	4.8
50.3	40.0- 63.2	2.3	21.8	17.9-26.5	3.0	93.0	82.1-104.0	4.3
52.2	37.7- 65.9	4.2	22.0	18.5-28.7	4.0	100.7	84.6-115.8	5.0
92.8	49.9-123.6	9.6	23.1	21.0-26.4	1.9	241.0	155.0-287.6	20.6
66.0	45.6- 79.0	8.0	22.5	19.0-25.4	2.0	127.2	98.6-152.2	13.7
134.2	120.0-149.3	6.2	16.3	12.2-21.9	4.0	162.5	32.1-292.8	60.2
72.5	48.9- 92.7	7.5	14.0	8.9-19.3	4.2	135.8	123.2-153.3	8.8
52.7	40.5- 67.5	3.3	19.9	16.5-21.5	2.4	92.4	80.0-108.1	3.0
51.4	31.3- 67.9	6.2	17.9	15.4-24.1	1.8	104.8	87.2-112.2	7.8
92.4[2]	31.3-149.3	1.6[3]	20.7[2]	8.9-28.7	0.8[3]	140.6[2]	32.1-306.1	4.1[3]

[1] Ten samples per animal.

[2] Mean for the 130 samples.

[3] Standard deviation.

TABLE XXX

MEAN VALUES FOR POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF NINE COWS AND HEIFERS USED IN THE STERILITY PROJECT THAT DID CONCEIVE

(Expressed in mg. per 100 ml.)

Blood[1]	Range	M.D.	Plasma[1]	Range	M.D.	Cell[1]	Range	M.D.
58.5	46.5-72.5	4.3	22.3	20.8-27.5	2.5	124.3	120.6-137.9	5.2
52.5	39.6-75.0	5.2	27.1	24.3-38.0	5.1	109.1	100.7-132.5	6.0
58.0	46.7-68.5	2.5	22.9	19.9-25.3	2.6	138.1	115.6-156.7	12.3
43.1	31.5-55.0	3.2	23.0	20.2-27.8	2.9	81.9	68.2- 97.4	6.9
74.5	50.0-86.7	4.5	23.8	19.2-27.4	3.5	158.2	122.7-187.0	9.9
59.8	47.8-69.3	2.7	18.9	16.0-30.9	3.9	113.4	100.9-133.8	6.3
50.5	42.8-66.0	3.4	18.3	14.8-20.8	2.3	111.4	97.4-123.5	4.7
38.4	20.3-62.5	8.6	16.0	12.8-23.9	3.3	135.6	111.3-150.0	12.2
57.9	40.0-77.5	7.4	17.2	13.7-21.4	2.3	114.7	94.7-148.3	19.1
54.8[2]	20.3-86.7	1.3[3]	21.1[2]	12.8-38.0	0.9[3]	120.7[2]	68.2-187.0	2.6[3]
64.4[4]	20.3-149.3[5]	0.36[6]	20.9[4]	8.9-38.0[5]	0.2[6]	132.5[4]	32.1-306.1[5]	0.8[6]

[1] Ten samples per animal.

[2] Mean for the 130 samples.

[3] Standard deviation.

[4] Mean for the 220 samples.

[5] Range for the 220 samples.

[6] Standard deviation for the 220 samples.

TABLE XXXI

RATIOS OF SODIUM AND POTASSIUM IN BLOOD OF COWS AND HEIFERS USED IN THE STERILITY PROJECT[1]

Blood Na/K	Plasma Na/K	Cell Na/K	Plasma Na/ Cell Na	Plasma K/ Cell K
		Sterile		
2.3	15.1	0.3	4.8	0.09
3.7	14.8	0.8	2.7	0.15
4.3	15.2	1.1	2.4	0.18
4.4	14.7	1.3	2.2	0.19
5.2	15.3	1.1	2.6	0.18
5.4	15.4	1.9	1.9	0.23
5.4	15.5	1.8	1.9	0.22
2.8	14.4	0.5	2.8	0.10
4.1	14.8	1.5	1.8	0.18
1.8	21.1	0.5	4.1	0.10
3.6	23.8	1.4	1.8	0.10
5.2	17.3	1.6	2.1	0.22
5.6	18.9	1.8	1.8	0.17
Av.[2] 4.1	16.6	1.2	2.5	0.16
		Conceived		
4.6	15.4	1.0	2.7	0.18
5.2	12.7	1.2	2.7	0.25
4.7	15.0	0.8	3.1	0.17
6.6	14.6	2.2	1.8	0.28
3.6	14.2	0.9	2.3	0.15
4.7	18.1	1.8	1.7	0.17
5.8	18.5	1.9	1.6	0.16
7.2	20.8	1.2	2.1	0.12
4.8	19.3	1.7	1.7	0.15
Av.[3] 5.2	16.5	1.4	2.2	0.18
Av.[4] 4.6	16.2	1.2	2.2	0.16

[1] Calculated from the data presented in Tables XXVII, XXVIII, XXIX, and XXV.

[2] Average for the 130 samples.

[3] Average for the 90 samples.

[4] Average for the 220 samples.

Cantarow and Trumper (92) stated that adrenocortical insufficiency causes an increased urinary excretion of sodium and a decreased excretion of potassium. The animals in the sterility project that did not conceive had lower sodium and higher potassium values than normal animals. It seems possible that the sterility encountered in these animals could have been caused by an endocrine disturbance since they had high values for potassium. The fact that adrenocortical insufficiency causes potassium retention supports this possibility. The study of the animals on the sterility project indicates that the sterility might possibly be due to adrenocortical insufficiency. If this is the case, the condition might possibly be related to human sterility.

Sodium and Potassium in Blood of Identical Triplets

Table XXXII presents the individual and the mean values obtained for sodium and potassium in whole blood, plasma, and cells for one set of identical triplets. The values for sodium and potassium in whole blood and plasma did not vary markedly from week to week. The weekly variations are larger in cells. The average values for the set of triplets agree quite well. Some of the variations might be due to the fact that these animals were very young during the period that they were bled.

TABLE XXVII

VALUES FOR SODIUM AND POTASSIUM IN WHOLE BLOOD, PLASMA, AND CELLS OF IDENTICAL TRIPLETS

(Expressed in mg. per 100 ml.)

	Blood	Plasma	Cell	Blood	Plasma	Cell	Blood	Plasma	Cell
					Sodium				
		T-66			T-67			T-68	
	271.5	320.0	173.0	261.0	322.8	135.5	261.8	340.0	128.6
	266.8	344.5	119.4	260.8	363.0	83.0	266.0	334.8	135.4
	266.0	344.5	122.0	265.3	342.0	105.8	267.5	351.5	92.9
	269.5	339.0	103.4	262.0	332.5	115.7	258.5	330.8	105.0
Av.[1]	268.4	337.0	129.4	262.3	340.1	110.0	263.4	339.3	115.5
					Potassium				
	76.0	23.6	182.4	77.3	23.5	186.7	86.8	25.4	191.4
	73.8	20.3	175.4	78.5	20.3	179.7	81.5	25.4	188.1
	75.9	25.0	172.3	73.8	24.6	176.0	76.8	26.0	182.2
	67.5	22.0	176.3	72.3	21.2	178.5	73.5	23.5	179.7
Av.[1]	73.3	22.7	176.6	75.5	22.4	180.2	79.6	25.1	185.3

[1] Average values.

SUMMARY

SUMMARY

1. The present study was carried out to determine the mean values for sodium and potassium in whole blood, plasma, and cells of normal adult dairy cows and calves. Studies were carried out to determine the effects of rations, environmental conditions, and certain abnormal conditions.

2. A comparison was made of the flame photometric and chemical methods for the determination of sodium and potassium in whole blood and plasma. The flame photometric method was found to be more reliable and reproducible than the chemical method.

3. A comparison was made of the preliminary treatments of trichloroacetic acid precipitation, dry ashing, and wet ashing for the determination of sodium and potassium in whole blood and plasma. The trichloroacetic acid precipitation and the dry ashing preliminary treatments were found to yield the same results.

4. Two hundred analyses were made on 100 normal adult dairy cows to determine the amount of sodium and potassium in whole blood, plasma, and cells. The values in mg. percent for sodium were: whole blood 283.2, plasma 341.5, and cells 180.7. The values in mg. percent for potassium were: whole blood 51.3, plasma 22.2, and cells 106.2.

5. No definite seasonal variations were noted for sodium, although potassium increased slightly during the winter months.

6. The ratios for sodium to potassium in whole blood, plasma, and cells, and cells and ratios of plasma sodium to cell sodium and plasma potassium to cell potassium were calculated.

7. The values determined for sodium and potassium in whole blood, plasma, and cells of ten pairs of identical twins on the same and different rations were found to be the same.

8. Low sodium and high potassium values were found in the blood of newborn calves when compared to the normal adult values. The values at birth in mg. percent for sodium were: whole blood 230.8, plasma 350.8, and cells 65.8. The values at birth in mg. percent for potassium were: whole blood 174.2, plasma 31.5, and cells 358.6. The values for sodium gradually increased and for potassium gradually decreased to a normal adult value at about twelve weeks of age.

9. No definite changes could be demonstrated for sodium and potassium in the blood of cows during the periods before, during, and after parturition.

10. Sterile animals were found to have lower sodium and higher potassium values than normal animals. These results indicated that the sterility was possibly due to an endocrine disturbance.

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SODIUM AND POTASSIUM
IN BOVINE BLOOD

By

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AN ABSTRACT

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Sodium and potassium are concerned in at least four fundamental physiologic processes: (1) the maintenance of normal water balance and distribution; (2) the maintenance of normal acid-base equilibrium (physiologic neutrality); (3) the maintenance of normal osmotic equilibrium; and (4) the maintenance of normal muscle irritability.

There have been fourteen papers published dealing with normal values for sodium and potassium in bovine blood. However, there are large discrepancies in the mean values reported. Most of this work was done by chemical methods. There have been only two papers reporting values by means of the flame photometer. These articles do not by any means give a complete blood picture for sodium and potassium in normal adult animals.

The present study was carried out to determine the concentration of sodium and potassium in whole blood, plasma, and cells of normal adult dairy cows and calves and to make a preliminary survey of the effect of rations, environmental conditions, and certain abnormal conditions.

A comparison was made of flame photometric and chemical methods. Sodium and potassium were determined flame photometrically by the internal standard method. A Perkin-Elmer flame photometer, Model No. 52-A, with a red-sensitive phototube and an acetylene flame was used to measure the amounts of sodium and potassium in the whole blood and plasma solutions. Sodium was determined chemically by the method of Weinbach (1), and the chloroplatinate procedure outlined by Peters and Van Slyke (2) was used to determine potassium. The flame photometric method was found to be more reliable and reproducible than the chemical methods.

A comparison was made of the preliminary treatments of trichloroacetic acid precipitation, wet ashing, and dry ashing. The trichloroacetic acid precipitation and the dry ashing preliminary treatments were found to yield the same results. Trichloroacetic acid precipitation was used as a preliminary treatment to remove the proteins from the whole blood and plasma samples.

Two hundred analyses were made on 100 normal adult dairy cows. The average values obtained for sodium were: whole blood 283.2, plasma 341.5, and cells 180.7 mg. percent. The values for potassium were: whole blood 51.3, plasma 22.2, and cells 106.2 mg. percent.

Low sodium and high potassium values were found in the blood of newborn calves when compared to the normal adult values. The values found at birth for sodium were: whole blood 230.8, plasma 350.8, and cells 65.8 mg. percent. The values at birth for potassium were: whole blood 174.2, plasma 31.5, and cells 358.6 mg. percent. The concentration of sodium gradually increased and potassium gradually decreased to a normal adult value at about twelve weeks of age.

Sterile animals were found to have lower sodium and higher potassium values than normal animals. These results may indicate that sterility may be associated with an endocrine disturbance.

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