THE EFFECT OF HIGH POTASSIUM INTAKE ON SHEEP AND RABBITS

by

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TABLE OF CONTENTS

THE EFFECT OF HIGH POTASSIUM INTAKE ON SHEEP AND RABBITS

INTRODUCTION

Grass tetany is a disease which has been observed in both cattle and sheep grazing wheat pasture in the Oklahoma and Texas Panhandles. The disease is often fatal, and mortality rates as high as 8% have been reported in sheep herds and 0.5% in cattle herds (43).

The economic problems which confront the cattle and sheep raisers are apparent when it is realized that millions of acres of wheat are sown yearly in the southwest wheat section and pasturing this wheat is a common practice.

In view of the serious economic losses in herds pastured on wheat, this study was undertaken in an effort to determine the cause of the disease.

The specific objectives of this study were: (1) To investigate the effect of a high potassium intake on sheep grazing wheat pasture; and (2) to attempt to produce the syndrome of grass tetany by feeding rabbits excessive amounts of potassium with a diet of dehydrated cereal grasses similar to the wheat forages of western Oklahoma and northern Texas.

REVIEW OF LITERATURE

The disease entity commonly known as grass tetany (wheat pasture poisoning, oat pasture poisoning or grass staggers) was first accurately characterized by Sjollema and Seekles (38) in the Netherlands in 1930. This disorder occurs chiefly among cattle and sheep during late pregnancy or early lactation (5, 6, 7, 18, 27, 31, 32). The most common symptoms are hyperirritability and muscular incoordination. Bulging eyes, twitching ears, head drawn back with tetanic convulsions of the neck muscles and difficulty in locomotion are symptoms which have been reported in many cases (3, 19, 22). Some cases have been reported (19) where the animals attempted to attack or repel anyone or anything approaching them.

Post-mortem findings of animals having had typical grass tetany consist of small hemorrhages on the surface of the heart, brownish-red muscle tissue, small cysts in the kidney and stoppage of the kidney tubules by calcium deposits (36).

The biochemical cause of this disorder is still not understood, despite nearly 25 years of work in this country and abroad. Sjollema and Seekles (38, 39, 40) reported that cattle suffering from the disease showed a sharp decrease in magnesium and ionic calcium in the serum. Serum inorganic phosphorus, however, varied within wide limits and appeared to have no relation to the occurrence of the disease.

Workers in many countries have reported hypomagnesia (2, 5, 8, 14, 21, 23, 37, 45) to be a commonly found abnormality in the blood of affected animals. Hopkirk (22) found serum magnesium decreased at the onset of the disease and remaining low for some time after acute symptoms were observed. Cows affected with the disease in New Zealand were found to have a higher serum inorganic phosphorus than uneffected cows (22). Attempts by these workers (22) to induce the disease in sheep by feeding KNO_3, $Na_2C_2O_4$, Na_2HPO_4 or casein were unsuccessful. However, a tendency for low serum magnesium was observed when sheep were placed on lush green pasture.

Allcroft (1) and Nicholason and Shearer (32) reported that low serum calcium was also associated with the disease in many cases.

In contrast to other workers, McMillan and Langham (26) reported that analyses of the serum of six affected cows grazing wheat pasture showed low calcium and phosphorus while magnesium was higher than normal. Harbaugh and Dennis (19) expressed doubt that cases of this type were actually grass tetany. Too, Barrentine (3) studying the disease in ewes grazing winter oats states that one invariably finds the hypomagnesia. Both calcium and phosphorus or either may be low.

Various explanations have been advanced to account for the underlying causes of the disease. Sjollema and Seekles (41) studying the influence of a high protein diet on cattle, observed symptoms similar to grass tetany with often fatal outcome. These workers found an increase in total blood protein while the urea and amino acid content remained normal. A high urinary protein excretion led them to believe there was kidney damage. This belief was later supported by postmortem findings.

Colby and Frye (12) and Barron, et al. (4) studied the effect of a high protein and calcium intake on the magnesium deficiency syndrome in rats. They found that either a high protein or calcium diet increased the severity of symptoms of magnesium deficiency, causing a marked depression of growth and increased mortality.

Barrentine (3) in 1948 suggested that the lush green pastures where grass tetany occurred contained too much protein for the ruminant. These pastures often had more than 20% protein. He purposed that the disease was a magnesium deficiency (possibly also a calcium deficiency) resulting from the inability of the animal to absorb either magnesium or calcium. The hypothesis was that bacteria of the rumen split ammonia from the protein in the forages in such large quantities that the magnesium is converted to the insoluble salt, $MgNH_4PO_4 \cdot 6H_2O$, in the small intestine. Calcium might also be removed in the same manner. Further studies in animals receiving sufficient magnesium and calcium to overcome the removal by ammonia did not alleviate the condition.

The theory of a mineral inbalance had been studied previous to 1939 with especial reference to magnesium and calcium. Mullin, et al. (29) studied the blood potassium in tetany of dogs and found in this case the serum content of this mineral was increased. Sighn and Sighn (37) and others (42) studied the neuromuscular transmission in frog muscle and found that potassium ions were necessary for transmission of nerve impulses. In 1945, Caldwell and Hughes (9) suggested a possible explanation for grass tetany based upon excessive potassium. These workers advanced the hypothesis that an inbalance between the mono- and di-valent ions of nerve tissue was responsible for the disease. Consumption of wheat high in potassium might result in increased permeability and conductivity of nerves and hence the hyperirritability observed in the animals. Further, excessive amounts of potassium might then "short circuit" the nervous system and produce the paralytic or comatose stage of the disease.

Walwrath, et al. (46) studying the composition of wheat forages in 1946 reported that the ratio of the sum of the sodium and potassium ions to the sum of the calcium and magnesium ions may implement a reference that grass tetany is associated with an inbalance between these elements.

Pearson, et al. (33) in a study of the calcium, magnesium and potassium content of blood serum of ewes fed high levels of potassium (approximately 5% as $KHCO_3$) concluded that there was no significant effect on calcium, magnesium or potassium in the blood serum. Meyer, et al.(28) reported that high potassium diets caused increased concentration of potassium in blood serum as well as all tissue.

Barrentine (3) reported cases of tetany in sheep grazing winter oats. A comparison of the forages led him to believe that the low magnesium content was responsible for a magnesium deficiency. Oats having 0.14% magnesium caused tetany, and oats with more than 0.20% magnesium caused no tetany. In these cases, the magnesium content of the serum dropped from 2.40 to 0.70 mg. percent and the symptoms occurred from 4 to 20 days after the animals were placed on the oat pasture. Garner (17) and Kunkel and Pearson (25) indicate that the magnesium in most forages are sufficient and available to the ruminant.

Despite the findings of investigators on the subject, the etiology and treatment of the disease of cattle and sheep grazing wheat pasture in the high plains area of western Oklahoma and northern Texas remained obscure. Workers at the Panhandle Station at Goodwell, Oklahoma (a joint endeavor of the Oklahoma Agricultural Experiment

Station and Panhandle A. and M. College) became interested in studying the disease and elicited the assistance of the chemistry staff at the main station at Stillwater. The data summarized in this thesis represents the contributions of various workers at the Panhandle Station and at Stillwater in addition to the author.

EXPERIMENTAL

Materials:

Blood samples were collected by venous puncture of the jugular vein of the sheep and by cardiac puncture of the rabbits. Coagulation was prevented through the use of lithium citrate. During 1950-51, the whole blood samples collected at Goodwell were refrigerated and flown to Stillwater on the day following bleeding. During subsequent years, separation of plasma was effected at Goodwell and the refrigerated plasma shipped by various means to Stillwater.

Methods:

Calcium - Blood serum calcium was determined by the method of Tisdall (44) as modified by Clark and Collip (10). Two ml. of serum are introduced into a 15 ml. centrifuge tube containing 2.0 ml. of water and 1.0 ml. of saturated ammonium oxalate solution. These were mixed and permitted to stand for 2 or 3 hours for precipitation of the calcium oxalate, centrifuged at 1200 r.p.m. for 10 minutes. The supernatant liquid was then decanted and the precipitate washed two times with dilute ammonium hydroxide (2% by volume). The tube was drained in an inverted position, 2.0 ml. of 1.0 N - H_2SO_4 were added, the mixture heated to 60° C. and titrated with 0.01 N-$KMnO_4$. Blank determinations were run and suitable corrections made.

Magnesium - The serum magnesium analyses from October 1950 to June 1951 were made by the Kunkel, Pearson and Schweigert (25) method. During the following year, the method of Denis (13) was used. This method is a modification of the Fiske and Subarrow (15) colorimetric method for the determination of phosphorus. In the Denis method (13) the serum magnesium is precipitated as $MgNH_4PO_4 \cdot 6H_2O$ after removal of calcium by the procedure described above. After washing the precipitate with ammonium hydroxide, the magnesium was determined by comparing, in the Evelyn colorimeter using a 660 mμ filter, the percentage transmission of the sample with a series of phosphorus standards having a known magnesium equivalent.

The Denis method, requiring precipitation and washing of the very fine $MgNH_4PO_4 \cdot 6H_2O$ precipitate with the possibility of loss, was cumbersome for routine analyses. For this reason, the colorimetric determination of magnesium depending on the color complex formed by the titan yellow-magnesium hydroxide reaction discovered by Kolthoff (24) in 1927 was investigated. The procedure used after June 1952 is mainly that Garner (16) with some modifications by Kunkel, et al. (25), Heagy (20), Platner (35) and the writer. The following is the procedure finally developed and used during 1953.

Reagents:

Magnesium stock standard - 4.9505 gms. of anhydrous $MgSO_4$ in one liter of solution (1 ml. = 1 mg. of magnesium).

Magnesium working standard - 5.0 ml. of the stock standard diluted to one liter (1 ml. = 5.0 μg. of magnesium).

Trichloroacetic acid (T.C.A.) - 10% wt./vol.

P.V.A. solution - 1.000 gm. of polyvinyl alcohol (DuPont medium viscosity, grade 51-05) is stirred in cold water and dissolved by gentle heating and stirring. The solution is diluted to one liter.

Titan yellow solution - 0.075% - 0.0375 gm. of titan yellow are dissolved in water, made to 500 ml. and filtered. The solution is freshly prepared each month, and stored in a brown bottle in the refrigerator.

Sodium hydroxide - 4N.

Procedure:

To 1.0 ml. of serum in a 15 ml. thick walled centrifuge tube, 5.0 ml. water and 2.0 ml. of T.C.A. are added, the tube closed with a clean rubber stopper and mixed for 30 seconds by shaking. The tube is centrifuged at 2000 r.p.m. for 15 minutes to get a water clear supernatant liquid. An aliquot of 4.0 ml. of the supernatant liquid is transferred to a clean colorimeter tube. Two ml. water, 1.0 ml. P.V.A. solution and 2.0 ml. titan yellow solution are then added to the tubes and mixed. A blank is prepared by mixing 5.0 ml. water, 1.0 ml. P.V.A. solution, 2.0 ml. titan yellow and 1.0 ml. T.C.A. solution in a clean colorimeter tube. A series of standards containing from 5 to 20 μg. of magnesium are prepared by adding 1.0 to 4.0 ml. of the working magnesium standard to a series of colorimeter tubes. To the standards are then added 1.0 ml. P.V.A. solution, 1.0 ml. T.C.A., 2.0 ml. of titan yellow solution and water to make the total volume of the standards 9.0 ml. The contents of all the tubes are mixed, and 2.0 ml. 4.0 N-NaOH are added to develop the color complex. After 10 minutes, the percentage transmittance is determined in an Evelyn photoelectric colorimeter with a 540 mμ. filter. The concentration of the serum magnesium can then be calculated by reference to the cabibration curve obtained from the analysis of the series of standard magnesium solutions.

Phosphorus - The procedure for the inorganic phosphorus determination is the Fiske and Subarrow (15) method with some minor modifications.

In a 15 ml. heavy wall centrifuge tube 0.5 ml. serum is added to 9.5 ml. of 10% T.C.A. The tube is closed with a clean rubber stopper and shaken for 30 seconds. The mixture is then centrifuged at 2500 r.p.m. for 15 minutes to get a clear supernatant liquid. Five ml. of the supernatant liquid are then transferred to a colorimeter tube containing 1.0 ml. of Molybdate II reagent and 3.5 ml. of water. The contents are mixed and 0.5 ml. of amino naphthol sulfonic acid color reagent are added. After 20 minutes the percentage transmittance is determined in an Evelyn photo electric colorimeter using a 660 mμ. filter. A calibration curve is prepared by analysis of a series of phosphorus standards and the serum concentration of inorganic phosphorus is calculated by references to this calibration curve.

Sodium and Potassium - Both sodium and potassium were determined by the direct intensity method using the Perkin-Elmer model 52 A flame photometer. Standards containing 50-160 p.p.m. sodium and 5-16 p.p.m. potassium were prepared from sodium chloride and potassium sulfate. The methods as outlined in the model 52 A instruction manual (34) for standardization of the instrument and preparing calibration curves were followed. The serum was prepared for the determination by diluting 1.0 ml. of serum to 25 ml. Both sodium and potassium were determined on this dilution.

Ionic calcium and magnesium - It was thought that possibly there were changes in the ionic calcium and magnesium content of the sheep serum. To attempt to follow these changes, if any, an investigation of methods for determining these ionic constituents was initiated.

The procedure of Nicholas (30) using a metal filtering cell in which a cellophane membrane is supported by a metal disk with small holes in it and filter paper was investigated. The serum ultrafiltrate was forced through the membrane by an atmosphere of nitrogen at a pressure of 60 pounds per square inch.

Results of the analyses of ultrafiltrates obtained in this manner agreed closely with that of the literature, but the four hours required to collect the ultrafiltrate from one sample limits the application to a small number of samples. Therefore the procedure of Clegg (11) for preparing serum ultrafiltrate was studied. In this method, the membrane or dialysis tubing containing the serum is supported by a nylon bag inside a centrifuge tube. Difficulty was encountered in keeping the membrane from slipping out of the nylon bag. To prevent evaporation of the ultrafiltrate, due to heat from the centrifuge, which was spinning at 4500 r.p.m. for 2 to 2.5 hours, the centrifuge cups were covered with a sheet of cellophane held in place by a rubber band. Results of this study are inconclusive and indicate the necessity for more work before a suitable precedure for simultaneous determinations of many samples routinely is developed.

SHEEP FEEDING TRIALS

Sheep were chosen initially as the experimental animal for several reasons. Economy dictated using an inexpensive experimental animal to acquire and manage. To avoid doing needless duplication of studies underway near Amarillo, Texas with cattle, sheep were preferred. Irrigated wheat pasture was limited and it was desirable to increase the number of animals per treatment by using a smaller animal with a lower feed requirement.

The studies were undertaken along two parallel lines. The first was to make maximum use of wheat pasture to see whether or not lush wheat pasture produced by irrigation would induce the condition of grass tetany. In the first year a second lot grazed wheat with added calcium chloride in the drinking water. In trials 1 and 2 potassium, as potassium chloride was administered to the sheep.

Parallel studies in dry lot attempted to induce a syndrome similar to wheat pasture poisoning by nutrition means. Continuing throughout the three year period to evaluate the potassium stress hypothesis, sheep were fed diets containing added potassium to increase the level to above that found in lush succulent wheat pasture. Potassium chloride was used during trials 1 and 2 and a mixture of potassium salts during trial 3.

Trial No. 1, 1950-51

This experiment was designed to study the effect of added calcium chloride in the drinking water of sheep grazing wheat, and of added potassium chloride in the ration of sheep in dry lot. Water and feed were supplied free choice to all lots.

Forty purebred Hampshire and 40 purebred Western ewes were used for this trial beginning in October 1950 and ending in May 1952. Rams were turned with all the ewes during August and removed on October 21, 1950. Lambing season was during January, February and March 1951. The 80 ewes were divided into four lots of 20 animals with each lot composed of 10 ewes of each breed.

These lots received the following rations:

Lot 1 was fed in dry lot a 50-50 mixture of ground sorghum fodder and alfalfa hay with some molasses (rations 1, 2, 11, 12 and 14 of table I).

Lot 2 received the same ration as lot 1 with potassium chloride added in sufficient quantities to the molasses to bring the potassium content of the ration up to 5.0% on a dry matter basis.

Lot 3 was kept on wheat pasture (composition at various times listed in table I) during the entire trial.

Lot 4 was kept on wheat pasture (table I) with 4.6 grams of calcium chloride consumed per head daily in drinking water.

All lots received a 10:1 sodium chloride : phenothiozine free choice during the entire trial. Forage analyses and lots receiving them are given in table I. Blood samples were taken monthly from all animals. A summary of the calcium, magnesium, phosphorus, potassium and sodium analyses are given in table II.

TABLE I

Wheat Forage and Dry Lot Feed Analysis
for Winter and Spring 1950-51

Sample No.	Description	Dry Matter %	Dry Matter Composition: Ash %	Protein %	Ether Ext. %	Crude Fiber %	N.F.E. %	Ca %	P %	Na %	K %	Mg %
1	Fodder fed lots 1 and 2	89.12	8.45	9.44	1.92	31.83	48.36	0.718	0.174	0.095	2.04	0.302
2	Blackstrap Molasses	74.99	11.60	---	---	---	---	---	---	---	---	---
3	Wheat plants Nov. 11,1950	94.81	13.53	24.26	5.10	16.12	40.99	0.353	0.264	0.105	5.08	0.295
4	Wheat plants Dec. 6,1950	94.03	12.54	19.94	3.95	15.39	48.18	0.324	0.266	0.094	3.96	0.298
5	Wheat grazed by lot 3 1-17-51	95.12	14.89	24.09	2.32	15.36	43.34	0.310	0.279	0.093	1.87	0.287
6	Wheat grazed by lot 4 1-17-51	93.96	16.06	19.96	2.55	20.14	41.29	0.357	0.197	0.106	2.06	0.223
7	Wheat fed lot 3 (2-7-51)	93.81	16.25	24.72	1.67	15.89	41.47	0.533	0.144	0.053	0.41	0.244
8	Wheat fed lot 4 (2-9-51)	93.47	21.55	23.91	1.69	14.70	38.15	0.508	0.139	0.067	0.57	0.288
9	Wheat fed lot 3 (3-13-51)	95.46	17.91	15.39	2.98	19.72	44.00	0.702	0.136	0.040	0.20	0.229
10	Wheat fed lot 4 (3-13-51)	94.74	29.19	10.92	1.65	22.52	35.72	0.644	0.116	0.046	0.40	0.319
11	Grain fed dry lots in Jan. and Feb., 1951	95.36	3.52	15.54	4.22	4.21	72.51	0.105	0.598	0.052	0.79	0.298
12	Fodder fed to dry lots	94.18	8.21	3.72	2.08	28.11	57.88	0.329	0.154	0.040	1.34	0.170
13	Wheat - lots 3 and 4 - April, 1951	96.85	17.43	29.69	3.64	16.43	32.81	0.620	0.406	0.847	5.55	0.305
14	Grain sample - lots 1 and 2 fed March and April, 1951	88.88	4.07	9.81	3.13	3.70	79.29	0.124	0.585	0.051	0.69	0.228

Table II
Average Composition of Sheep Plasma
All Values Given in Mg %

		1950		1951				
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Calcium	Lot 1	9.5	10.8	9.1	9.8	8.7	9.2	9.5
	2	10.0	10.4	8.4	9.9	9.1	9.2	9.4
	3	9.4	10.5	9.6	9.9	10.1	10.2	10.6
	4	9.8	11.3	8.8	9.6	10.0	10.5	10.4
Magnesium	Lot 1	1.55	1.54	1.60	1.45	1.36	1.74	2.17
	2	1.53	1.41	1.44	1.31	1.22	1.70	1.24
	3	1.58	1.32	1.33	1.05	1.31	1.06	1.45
	4	1.59	1.30	1.32	0.92	1.22	1.00	1.17
Phosphorus	Lot 1	5.3	5.0	4.6	4.3	5.6	7.9	7.2
	2	4.7	5.2	4.6	4.9	5.2	7.2	7.0
	3	4.3	6.3	4.6	4.7	4.5	3.7	6.1
	4	4.8	5.5	4.7	4.2	5.2	5.7	5.6
Potassium	Lot 1	23.7	27.1	22.5	21.6	27.4	21.8	30.1
	2	23.7	27.8	23.8	21.4	27.1	23.9	34.3
	3	24.8	27.2	25.1	20.2	27.4	25.4	32.1
	4	24.2	30.7	23.9	19.9	26.4	22.9	29.5
Sodium	Lot 1	290	308	314	321	313	307	313
	2	299	306	304	316	294	302	310
	3	294	291	323	321	305	296	304
	4	296	322	305	312	312	298	314

Discussion

During this trial lots 1 and 2 received the rations as noted in table I. Lots 3 and 4 were on wheat pasture the composition of which varied from time to time as indicated in table I.

Dry lot feeding of lot 2 with high amounts of potassium chloride had no significant effect on the weight of the ewes, the number or weight of lambs born and analysis of blood showed no significant variation of mineral composition from the control lot 1 (table II). Blood plasma magnesium in lots 3 and 4 tended to show a slight decline in

February and April. The inorganic phosphorus level declined during late gestation (i.e. January) and remained low during the following months of heavy lactation. Supplementation of lot 4 diet with calcium chloride in the drinking water had no adverse effect on blood mineral composition or the physiological state of the animal.

Conclusions:

1. High levels of potassium chloride in sheep diets had no effect on the ionic levels of various minerals in the blood and did not produce symptoms of wheat poisoning.

2. Animals grazing wheat pasture appeared perfectly normal and no effect of addition of calcium chloride to the drinking water was noted.

Trial No. 2, 1951-52

Insofar as the dry lot feeding was concerned, this lot was essentially a repetition of trial 1, with minor modifications to refine the technique. Animals grazing wheat were to be treated as previously except potassium chloride was to replace the calcium chloride in the drinking water to still further stress the animal with high potassium intake.

This trial was conducted with 40 ewes, divided into four lots of 10 animals. All ewes were placed with rams on October 4, 1951. This established the lambing season in March and April rather than in midwinter as in the previous trial. This was done in order to avoid, if possible, the adverse effect of bad weather during the lambing season. To control the amount of feed intake and insure consumption of the salt supplement, the dry lot rations during this trial were pelleted.

It was expected to have a control and high potassium lot in dry lot feeding and a control and high potassium lot on wheat pasture. However, adverse growing conditions prevented the availability of wheat pasture until April 14, 1952. Therefore the lots received the following treatments:

Lot 1 received 3.5 lbs. daily of the control sheep ration (No. 2 table III) for the entire trial.

Lot 2 received 3.5 lbs. daily of the high salt sheep ration (No. 1 table III) for the entire trial. This ration was composed of a pelleted mixture of 570 lbs. of ground milo, 1276 lbs. of ground hegari fodder and 154 lbs. of potassium chloride.

Lot 3 received the same treatment as lot 1 until April 14, 1952 at which time the lot was transferred to wheat pasture and fed 116 grams of potassium chloride per head daily in drinking water.

Lot 4 received the same treatment as lot 1 until April 14, 1952 at which time the lot was transferred to wheat pasture with no feed supplementation.

All lots received a 10:1 sodium chloride : phenothiozine mixture free choice during the trial. All sheep were weighed and bled monthly. Blood plasma was analyzed for calcium, magnesium, phosphorus, potassium and sodium. Birth weight of lambs and shearing weight of the ewes were recorded. Forage analyses at various times during the trial were recorded (table III).

TABLE III

Analysis of Feeds - Sheep Trial 1951-52

Description	Ration No.	Dry Matter %	Dry Matter Composition: Ash %	Protein %	Ether Extract %	Crude Fiber %	N.F.E. %	Ca %	P %	Na %	K %	Mg %
High salt sheep ration.	1	93.35	17.09	7.02	2.23	9.49	64.17	0.416	0.208	0.193	5.50	0.236
Control sheep ration.	2	93.18	9.76	7.09	2.69	13.00	67.46	0.336	0.234	0.080	1.90	0.222
Ground wheat - North pasture, April 14.	3	92.98	12.75	29.75	4.28	17.24	35.98	0.401	0.457	0.027	4.51	0.157
Ground wheat - South pasture, April 14.	4	93.24	13.00	26.90	4.34	16.85	38.91	0.405	0.423	0.027	4.23	0.136
Ground wheat - South pasture, April 27.	5	93.59	25.40	22.66	3.22	19.75	28.97	0.395	0.431	0.043	4.12	0.215
Ground wheat - North pasture, April 27.	6	93.03	15.44	22.92	4.18	20.67	36.79	0.412	0.549	0.022	4.72	0.246
Ground wheat - North pasture, May 23.	7	93.43	7.01	10.68	1.61	30.17	50.53	0.235	0.269	0.016	2.00	0.098
Ground wheat - South pasture, May 23.	8	94.17	8.97	7.69	1.00	31.46	50.88	0.186	0.337	0.016	1.77	0.070

TABLE IV

Average Composition of Sheep Plasma 1951-52
All values in mg. %

	1951			1952						
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr. 20	May 12	May 24	June 6
					Calcium					
Lot 1	10.3	10.2	10.4	9.5	9.6	9.8		9.9	9.6	9.7
2	10.0	10.1	9.9	9.3	9.5	9.1		9.5	9.3	9.5
3	10.0	10.9	9.7	9.2	9.5	9.5	9.8	9.9	9.2	9.8
4	9.9	11.3	10.4	9.6	10.0	9.8	10.1	10.1	10.1	9.9
					Magnesium					
Lot 1	2.18	2.41	2.94	2.66	2.67	2.46		2.49	2.31	1.90
2	1.93	2.30	2.86	3.49	2.02	2.40		2.53	2.22	2.08
3	2.15	2.41	2.55	2.75	2.27	2.11	1.90	1.89	2.28	1.90
4	2.07	2.37	2.67	2.73	2.20	2.40	1.72	2.22	1.98	1.90
					Phosphorus					
Lot 1	6.10	5.18	3.51	3.61	3.61	2.81		3.44	4.08	3.63
2	6.75	6.04	5.10	3.95	4.10	3.45		3.20	4.12	3.72
3	6.13	4.59	3.84	3.21	3.62	2.73	3.03	3.87	3.85	3.73
4	6.13	5.01	3.91	3.22	3.63	3.00	3.40	3.29	3.59	3.37
					Potassium					
Lot 1	19.9	20.3	21.3	19.4	19.3	22.0		18.9	21.3	22.3
2	18.1	21.0	23.1	22.2	20.4	22.8		19.2	20.6	21.3
3	18.9	19.6	20.3	19.9	18.3	21.0	22.8	20.1	20.9	20.6
4	19.4	19.1	20.8	22.0	18.3	22.3	22.7	20.8	20.3	21.0
					Sodium					
Lot 1	312	313	300	311	300	300		312	311	309
2	306	316	297	314	308	292		318	303	296
3	313	306	301	307	300	291	315	317	307	304
4	309	314	304	311	301	292	311	314	311	307

Lots 3 and 4 transferred to wheat pasture April 14, 1952

TABLE V

Average Animal Weight by Lots
All values in pounds

	1951			1952					
	10-4	11-3	12-3	1-8	2-1	3-1	4-1	5-1	6-6
Lot 1	97.5	99.0	99.5	107.0	109.5	110.5	104.0	98.5	108.5
Lot 2	98.0	98.0	100.0	107.5	107.5	112.0	105.0	101.0	106.5
Lot 3	107.0	107.5	111.0	124.0	123.5	121.5	111.5	104.5	111.5
Lot 4	99.5	100.5	104.5	116.0	116.0	127.5	108.5	103.0	111.5

Discussion

Prior to April 14, 1952 lots 1, 3 and 4 received the same dry lot feeding treatment, i.e. ration No. 2 table III, containing 1.90% potassium. During this same time lot 2 received ration No. 1 which contained 5.50% potassium. The blood plasma composition (table IV) showed little change except for a slight decrease in inorganic phosphorus occurring in the early months of 1952 when the ewes were in late pregnancy and continuing to the end of the trial while they were in a period of heavy lactation. This decrease is of doubtful significance insofar as being related to dietary potassium stress was concerned.

Lots 3 and 4 were transferred to wheat pasture on April 14, 1952. Lot 3 received the potassium chloride in the drinking water. Blood analyses during this period showed a slight decrease in serum magnesium but at the terminal bleeding on June 6, 1952 all lots were approximately the same (table IV).

Involuntary exercise of the sheep by chasing them around the pasture had no apparent ill effect. No symptoms of grass tetany or hyperirritability were observed in any animal at any time during the entire trial.

The weight gains of the ewes during the trial (table V) was an average of 11.0 pounds per ewe in lot 1, 8.5 pounds in lot 2, 4.5 pounds in lot 3 and 12.0 pounds in lot 4. The average birth weight of the lambs by lots were: 7.9 pounds in lot 1, 7.6 pounds in lot 2, 7.7 pounds in lot 3 and 7.4 pounds in lot 4. There were 9 lambs born to ewes in lot 1, 8 lambs in lot 2, 8 lambs in lot 3 and 9 lambs in lot 4. The shear weight of the dry lots and wheat pasture lots differed quite a bit. Lots 1 and 2 had an average shear weight of 9.3 pounds per ewe. These two lots had access to shelter at all times. Lots 3 and 4, which had shelter only during lambing season, sheared an average of 10.2 and 11.8 pounds respectively.

Conclusions:

1. No symptoms of grass tetany or other disorders were observed in sheep fed 5.0% potassium in a diet of pelleted sorghum fodder and milo.

2. Administration of 116 grams of potassium chloride per head daily in the drinking water of sheep on wheat pasture produced no adverse effects.

3. Sheep grazing wheat pasture showed no wheat poisoning symptoms.

4. The mineral constituents of the sheep plasma remained the same whether or not the animal received a high potassium diet.

Trial No. 3, 1953

This trial was designed to continue the study of the effect of high potassium diets on sheep. In an effort to duplicate the alkalinity of the wheat plant the potassium was administered as a mixture of potassium salts. Fifty percent of the potassium was administered as potassium chloride, 35% as potassium bicarbonate, and 15% as potassium dihydrogen phosphate.

Twenty ewes divided into 2 lots of 10 ewes were used during this trial. Both lots were fed in dry lot receiving the following treatments:

Lot 1 received daily 2 pounds of a pelleted mixture containing 636 pounds of cottonseed meal and 1364 pounds of ground milo per ton.

Lot 2 received daily 2 pounds of a pelleted mixture containing 700.2 pounds of cottonseed meal, 1115.2 pounds of ground milo, 76.2 pounds of potassium chloride, 71.6 pounds of potassium dihydrogen phosphate and 36.8 pounds of potassium bicarbonate per ton.

Both lots went on trial on January 12, 1953. Blood analyses were made on January 12 and February 13 bleedings.

TABLE VI

Serum Composition of Sheep - Trial 3
All values are in mg. %

Animal No.	Calcium Jan.	Calcium Feb.	Magnesium Jan.	Magnesium Feb.	Phosphorus Jan.	Phosphorus Feb.	Potassium Jan.	Potassium Feb.	Sodium Jan.	Sodium Feb.
Lot 1 - Control										
3	11.2	11.1	2.34	2.32	5.90	3.03	17.9	17.5	293	298
4	10.0	10.5	2.34	2.86	4.33	4.30	19.0	20.5	303	308
11	8.8	11.2	2.66	2.30	2.93	3.88	18.6	19.8	303	313
17	9.2	10.8	2.14	2.40	1.95	3.05	17.5	17.9	288	288
22	9.8	11.1	2.38	2.30	2.58	3.25	18.3	17.5	293	303
23	11.0	11.1	1.96	1.98	2.68	2.78	16.8	16.0	303	303
24	10.4	11.0	1.78	2.26	2.88	2.90	18.3	17.9	288	293
25	13.1	9.3	1.92	2.18	4.20	3.75	17.9	17.5	298	303
29	11.5	11.2	2.22	2.30	3.43	3.18	17.5	17.9	298	308
31	----	10.6	----	2.30	2.95	3.13	21.0	15.8	265	278
Average	10.5	10.8	2.19	2.32	3.38	3.32	18.2	17.8	293	300
Lot 2 - High Potassium										
2	11.3	10.4	2.58	2.32	4.10	3.55	19.0	17.9	308	308
8	9.7	10.1	2.24	1.94	3.75	4.30	18.3	18.3	303	298
14	9.9	12.2	2.74	2.54	3.00	4.63	18.6	22.0	293	313
18	10.9	10.5	2.72	2.48	3.38	4.03	17.9	20.9	288	298
26	10.6	12.5	2.10	2.80	3.33	4.05	20.0	21.6	298	303
27	11.0	11.3	1.84	2.72	2.60	4.03	16.8	20.5	293	303
30	12.0	12.0	2.38	2.26	2.80	3.63	19.3	19.8	303	303
32	11.3	11.8	2.26	2.54	3.10	3.95	17.5	19.0	273	288
36	10.3	11.5	2.24	2.44	2.65	3.83	17.1	19.0	298	293
38	10.2	10.6	2.38	2.34	3.25	3.63	18.6	20.9	293	303
Average	10.7	11.3	2.35	2.54	3.20	3.96	18.3	20.0	295	301

Discussion

Blood analyses for calcium, magnesium, phosphorus, potassium and sodium showed no deviation among lots during the trial (table VI). The weight of lambs born during the trial in both lots were approximately the same. Shear weight of the ewes as well as final weights were normal and no variation among lots was noted.

Conclusion:

1. Supplementation of dry lot feeding of sheep with an alkaline potassium salt mixture did not have any adverse effect on serum concentration of minerals.

2. No symptoms of grass tetany or changes in physiological state of the ewes were observed when high potassium diets were administered.

RABBIT FEEDING TRIAL

Trial No. 1, 1953

From the reports of workers at the PanTech Field Station near Amarillo, Texas, it seemed possible that the rabbit might be used to study the effect of high potassium stress by feeding a diet of ground cereal grasses, having approximately the same composition as wheat grasses grown in the Texas and Oklahoma panhandles, to this animal. Dehydrated cereal grasses obtained from the Cerophyll Laboratories of Kansas City, Missouri were used throughout the trial. The potassium supplement was composed of an alkaline mixture of potassium salts. Forty percent of the total potassium in the salt mixture was supplied as potassium chloride, 10% as potassium sulfate, 30% as potassium acetate and 20% as potassium bicarbonate.

Twenty female rabbits with an average weight of about 1.6 kg. were divided into five lots of four rabbits and placed in Oakes chick brooders for feeding and observation.

Each lot received approximately 600 grams of dehydrated cereal grasses (sample No. 1, table VIII) for the first 19 days of the trial. Initial and weekly weights of each rabbit were recorded (Appendix).

Beginning on the 20th day of the trial a second sample of cereal grasses (No. 2) was fed to all lots. To prevent excessive waste by the rabbits, this and all subsequent rations were mixed with sufficient water to make a thick dough.

On the 35th day of the trial all lots were placed on sample No. 3. Lots 1 and 2 each received 600 grams of sample No. 3 daily. Lots 3, 4 and 5 each received 600 grams of sample No. 3 daily with 31.1 grams of the potassium salt mixture to bring the total potassium content of the diet up to or above 5.0%.

At the end of the trial, blood samples were taken from all rabbits by cardiac puncture and analyzed for calcium, magnesium, phosphorus, potassium and sodium. A summary of the blood composition is given in table IX.

TABLE VII

Growth Rate of Rabbits Fed Dehydrated Cereal Grasses and Dehydrated Cereal Grasses Plus Potassium Salts by Lots
All values in grams

Lot No.	Treatment	End of Week								
		Initial	1st	2nd	3rd	4th	5th		6th	7th
1	Control	6887	7030	7795	7535	9070	9410	Lots 3, 4 and 5 went on high potassium diet	10435	10760
2	Control	6781	7016	7345	7010	9030	9980		10555	11131
3	High potassium	5990	6654	7255	6800	8680	9075		9800	10665
4	High potassium	5882	6403	7095	6560	8470	9205		9920	10275
5	High potassium	5909	6498	6865	6515	8310	9170		9530	9808*
Average control		6834	7023	7570	7273	9050	9695		10495	10948
Average high potassium		5907	6498	7071	6625	8486	9150		9750	10249*

* Rabbit X-101 omitted from these averages.

TABLE VIII

Analyses of Cereal Grasses - Rabbit Trial No. 1

Sample No.	Dry Matter %	Dry Matter Composition in %								
		Ash	Protein	Ether Extract	Crude Fiber	N.F.E.	Ca	P	K	Na
1	90.48	17.24	22.79	6.33	15.91	37.73	0.96	0.372	3.03	0.48
2	91.10	11.90	23.01	3.82	14.88	46.39	0.49	0.395	2.80	0.57
3	93.44	12.64	24.91	4.74	15.17	42.54	0.51	-----	2.90	0.59

TABLE IX

Summary of Clinical Composition of the Blood of
Rabbits Fed Cereal Grasses and Cereal Grasses Plus Potassium Salts
All values in mg. % are lot averages

Lot No.	Treatment	Ca	Mg	P	K	Na
1	Control	12.1	3.05	4.04	34.1	276
2	Control	11.5	3.26	4.33	35.3	273
3	High potassium	10.5	3.41	4.38	35.6	273
4	High potassium	10.8	3.20	4.13	34.6	274
5	High potassium	11.2	2.62	3.69	34.6	277
Average control lots		11.8	3.16	4.19	34.7	275
Average high potassium lots		10.8	3.08	4.07	34.9	275

Discussion

The dehydrated cereal grasses used in this trial had approximately the same composition (table VIII) as the wheat forages in the sheep trials. During the first 5 weeks, on a diet of approximately 3.0% potassium, no symptoms of hyperirritability were observed. Growth during this phase of the study seemed to be about normal with the exception of the third week. It will be noted that the change in ration and the method of wetting the feed occurred two days before the third weekly weighing. With the large weight gains the following week (table VII) it is believed that the change in feeding methods may account for the weight losses of the third week which appeared in all lots.

During the feeding of the high potassium diet to lots 3, 4 and 5 it will be noted that weight gains (table VII) were approximately the same as the control lots. Attempts to excite the rabbits with loud noises, shrill whistling and such had no apparent ill effect.

A summary of the blood analyses (table IX) showed no obvious differences between control and high potassium lots. All the constituents of the blood were within normal limits. Blood analyses of the individual animals are given in the Appendix.

Conclusions

1. No hyperirritability or other gross abnormalities were observed in rabbits fed dehydrated cereal grasses or dehydrated cereal grasses plus a mixture of potassium salts as the sole ration for a period of several weeks.

2. Weight gains were about normal and unaffected by the additional potassium salts.

SHEEP SERUM COMPOSITION - YEARLY AVERAGES PER LOT

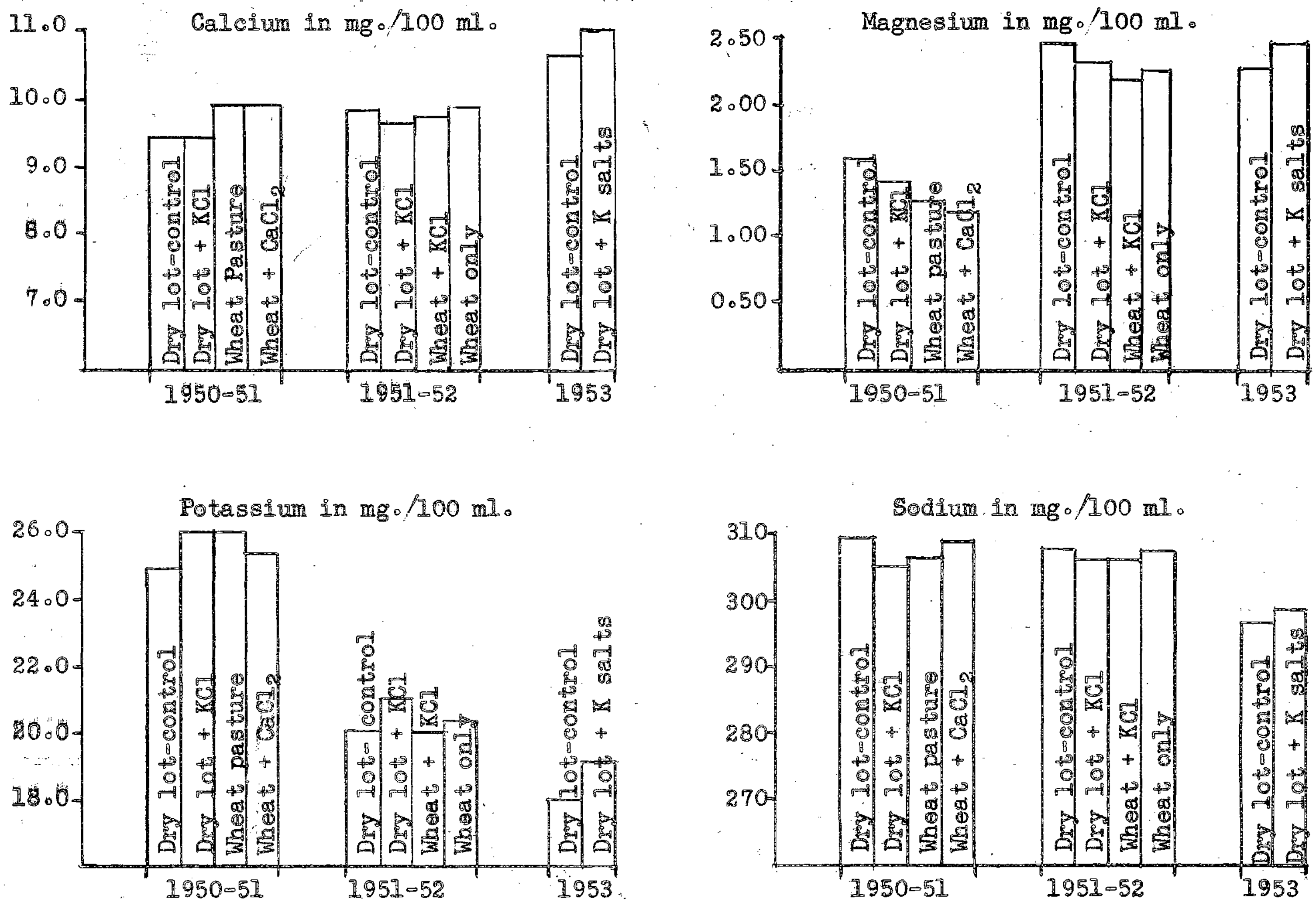

FIGURE I

SUMMARY

Sheep grazing succulent wheat pasture during trials 1 and 2 showed no ill effects and the serum concentration of calcium, magnesium, phosphorus, potassium and sodium was within normal limits at all times. Supplementation of wheat pasture with calcium chloride in trial 1 and potassium chloride in trial 2 showed no adverse effect either in the mineral content of blood serum (Figure I) or in the physiological state of the animals.

Supplementation of a dry lot ration with potassium chloride or a mixture of potassium salts having approximately the same alkalinity as wheat ash was ineffective in inducing the symptoms of grass tetany. All blood serum components examined were within normal limits at all times (Figure I). Normal growth, wool production and lamb crops were observed in all trials.

A salt mixture similar to that used in sheep trial 3 produced no symptoms of grass tetany or hyperirritability when fed to rabbits with dehydrated cereal grasses in sufficient quantities to raise the potassium level of the diet to 5.0%. Growth of the control and experimental animals was approximately the same.

It therefore seems that an induced potassium stress in sheep and rabbits was ineffective in producing the symptoms of grass tetany and hence this particular hypothesis of the cause of the disease is not supported.

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APPENDIX

Complete Record of Sheep Plasma Composition
During Sheep Feeding Trial No. 2 and
Rabbit Growth Record During
Rabbit Feeding Trial

Calcium Composition of Sheep Plasma in mg. %.

Animal No.	1951 Oct.	1951 Nov.	1951 Dec.	1952 Jan.	1952 Feb.	1952 Mar.	1952 Apr.	1952 May	1952 May	1952 June
			Lot No. 1 - Dry Lot Control							
6	10.9	9.15	9.7	8.9	10.0	9.7		10.2	10.2	10.4
18	9.9	9.7	11.3	9.2	8.6	8.9		9.1	8.8	10.0
19	9.5	10.7	9.8	9.1	8.9	9.1		9.5	9.4	8.9
21	9.1	11.1	10.8	9.1	9.4	10.8		10.1	9.4	9.5
28	11.4	9.8	10.2	9.1	10.1	9.1		10.7	9.7	8.9
10	9.4	10.6	11.3	10.6	9.6	11.0		10.5	10.0	9.5
33	9.5	10.3	10.0	9.3	9.1	10.2		9.5	9.6	9.6
34	10.8	10.2	10.4	9.8	9.1	9.5		10.1	9.9	10.1
38	11.6	10.1	9.9	9.6	10.7	9.6		9.3	9.0	10.7
40	11.3	10.2	10.4	10.3	10.5	9.9		10.2	10.3	9.8
			Lot No. 2 - Dry Lot + KCl							
1	9.5	11.0	10.8	9.5	10.4	9.3		9.4	8.9	9.6
2	8.6	10.2	10.3	9.3	10.7	8.9		9.3	10.2	10.0
3	10.0	10.5	9.1	10.2	8.9	10.1		9.6	8.8	9.8
4	9.9	10.0	9.2	9.4	8.7	8.4		9.1	8.7	8.6
9	9.2	9.9	9.8	8.6	9.3	8.9		8.9	8.7	9.1
12	11.3	9.65	10.2	9.7	9.5	9.5		9.5	7.9	9.9
13	10.5	10.8	10.4	9.2	9.8	9.0		9.5	10.4	9.1
14	10.9	9.9	10.2	9.0	8.9	8.9		9.8	9.7	10.2
20	9.5	9.7	9.8	9.1	10.0	9.0		9.7	10.0	8.7
27	10.3	9.2	9.4	8.7	8.9	9.4		10.0	9.8	9.8
			Lot No. 3 - Wheat Plus KCl							
8	10.4	10.4	9.1	9.6	9.4	9.2	10.4	8.8	9.4	8.8
16	9.3	9.9	10.0	9.0	9.1	9.4	9.2	9.2	7.8	9.4
17	9.8	10.4	9.6	9.5	9.2	8.7	10.1	9.9	9.8	10.5
22	9.1	11.6	10.2	9.4	9.4	9.7	9.2	10.4	9.9	10.1
25	10.0	11.1	10.1	8.8	9.1	9.4	9.6	9.7	8.7	8.2
29	10.1	10.7	9.8	8.7	9.0	9.2	9.0	10.4	9.1	10.1
31	10.7	12.0	9.4	8.9	10.4	8.9	10.2	10.5	9.4	10.3
32	10.4	11.2	9.3	9.4	10.0	10.5	9.1	10.4	9.0	9.6
35	9.9	11.1	10.1	9.7	9.7	9.6	10.2	9.9	10.2	10.4
36	9.9	11.0	9.2	8.9	9.8	10.0	11.2	9.7	8.7	10.1
			Lot No. 4 - Wheat Pasture							
5	8.5	9.9	11.0	9.4	9.3	10.6	10.1	9.2	8.7	9.5
7	10.1	11.8	10.8	9.3	10.7	10.9	11.4	10.5	10.9	10.5
11	10.4	12.3	11.0	8.9	10.8	10.3	10.7	9.5	9.2	8.8
15	10.9	10.7	11.4	9.9	10.1	8.8	9.8	9.6	9.3	9.5
23	10.3	12.4	10.1	10.0	9.4	8.9		9.8	9.1	9.8
24	9.3	10.5	10.3	9.3	10.4	9.0	10.1	9.9	9.4	10.1
26	8.7	11.6	10.7	9.5	10.1	10.6	10.4	10.9	8.9	10.4
30	10.2	11.1	9.9	9.2	9.4	9.7	9.7	10.6	9.3	---
37	10.0	11.2	9.1	10.9	9.6	9.5	10.2	11.0	10.2	9.4
39	10.9	11.7	9.9	10.1	10.5	9.4	8.8	10.9	9.1	10.0

Mg Composition of Sheep Plasma (mg. %)

Animal No.	1951 Oct.	Nov.	Dec.	1952 Jan.	Feb.	Mar.	Apr. 20	May 12	May 24	June 6
			Lot No. 1 - Dry Lot Control							
6	2.10	2.63	3.29	2.81	2.48	2.34		2.06	2.36	2.71
18	1.88	2.55	2.75	2.63	2.74	2.91		2.83	2.25	1.40
19	2.03	2.48	2.65	2.38	2.31	2.93		2.28	2.06	1.71
21	2.24	1.93	2.75	2.45	2.31	2.30		2.35	2.40	2.36
28	2.49	2.59	3.00	2.58	3.06	1.91		2.90	2.41	1.66
10	2.08	2.75	3.01	2.68	2.29	2.75		2.31	2.15	1.80
33	2.19	2.23	3.10	2.55	2.92	2.21		2.68	2.86	2.31
34	2.24	2.46	2.88	2.55	2.44	2.48		2.44	2.21	1.20
38	2.41	2.25	2.96	3.01	3.14	2.29		2.83	2.48	2.15
40	2.18	2.28	3.01	2.96	3.06	2.50		2.23	1.99	1.69
			Lot No. 2 - Dry Lot + KCl							
1	1.49	2.06	2.98	2.02	2.09	2.75		2.88	1.90	2.90
2	1.79	2.23	2.42	2.19	1.90	2.48		2.35	2.34	2.24
3	2.13	2.29	3.10	1.90	1.74	2.40		1.94	2.69	2.19
4	1.60	2.01	2.98	2.48	2.03	2.41		2.21	2.38	1.25
9	1.59	2.29	2.88	3.01	1.89	2.28		2.63	2.30	2.85
12	2.33	2.21	2.55	2.58	2.62	2.34		2.80	2.46	1.38
13	1.25	2.60	2.67	2.81	2.81	2.50		2.56	2.38	2.35
14	2.33	2.57	3.21	2.21	2.09	1.95		2.66	1.93	1.90
20	2.41	2.50	3.12	2.92	1.60	2.40		2.59	1.93	2.48
27	2.38	2.28	2.72	2.75	1.44	2.44		2.75	1.89	1.34
			Lot No. 3 - Wheat Plus KCl							
8	----	2.53	2.65	2.34	2.18	2.30	1.50	2.35	2.24	2.16
16	2.28	2.59	2.00	2.81	2.18	1.68	2.15	2.08	----	2.31
17	2.21	2.58	2.67	2.54	2.53	1.89	2.08	1.63	1.88	1.15
22	2.46	2.35	2.25	2.73	2.78	2.04	2.11	1.56	2.15	
25	2.41	2.41	2.75	2.99	2.21	2.09	1.96	1.95	2.30	1.50
29	1.86	2.50	1.87	3.10	2.71	2.44	1.50	1.16	2.40	2.10
31	2.16	2.25	2.72	2.75	1.71	2.48	1.79	2.53	2.34	2.20
32	2.23	2.33	2.75	2.48	2.11	2.09	2.04	1.98	2.66	2.48
35	1.66	2.34	3.21	3.33	1.84	1.90	1.90	1.64	2.30	2.03
36	2.14	2.29	2.65	2.44	2.45	2.28	2.06	1.99	----	1.18
			Lot No. 4 - Wheat Pasture							
5	1.46	2.04	2.88	3.09	2.00	2.36	2.15	2.66	2.45	1.88
7	2.04	2.53	2.90	2.40	2.09	2.09	1.65	1.71	----	1.44
11	----	2.48	2.93	2.46	2.11	2.59	1.54	2.16	2.12	2.18
15	1.70	2.53	2.24	2.55	2.31	2.21	1.70	1.98	1.34	2.71
23	1.90	2.20	2.10	2.60	1.50	2.21	1.66	2.30	1.54	1.53
24	2.41	2.35	2.33	2.90	2.65	2.89	1.53	1.74	1.82	2.33
26	2.03	2.55	3.01	3.03	1.65	2.40	2.66	2.43	1.96	1.29
30	2.08	2.31	2.15	2.55	2.30	2.36	1.30	2.69	1.95	1.96
37	2.50	2.20	3.10	3.01	2.78	2.50	1.51	1.93	2.30	1.78
39	2.50	2.55	3.10	2.71	2.58	2.46	1.48	2.69	2.28	----

Inorganic P Composition of Sheep Blood (mg. %)

Animal No.	1951 Oct.	1951 Nov.	1951 Dec.	1952 Jan.	1952 Feb.	1952 Mar.	1952 Apr. 20	1952 May 12	1952 May 24	1952 June 6
			Lot No. 1 - Dry Lot Control							
6	6.92	3.80	2.33	2.40	2.08	2.60		3.03	3.33	3.20
18	4.80	4.50	2.58	3.68	2.93	2.48		2.85	3.90	2.95
19	5.48	4.20	2.53	3.28	2.08	2.58		2.68	4.05	2.80
21	6.72	4.63	3.18	2.65	3.08	2.63		2.35	3.85	3.65
28	6.44	5.18	4.43	3.75	3.93	2.28		3.15	3.62	4.33
10	6.20	6.48	4.65	5.00	5.83	2.68		4.50	4.93	4.93
33	5.32	5.68	2.78	3.53	3.25	2.15		3.70	4.28	3.20
34	5.76	4.33	3.95	3.58	3.43	2.90		4.34	4.05	3.10
38	6.60	6.20	4.88	4.15	4.38	4.08		3.43	5.18	3.78
40	6.80	6.83	3.85	4.05	5.15	3.78		4.45	3.60	4.33
			Lot No. 2 - Dry Lot + KCl							
1	5.40	5.43	3.35	4.05	3.05	2.83		2.38	5.25	4.00
2	7.92	5.08	6.03	4.80	5.42	4.30		3.82	5.05	3.20
3	6.28	5.45	3.75	2.91	3.20	2.60		2.93	3.36	3.18
4	8.48	7.95	6.13	5.62	5.70	3.83		3.58	4.90	5.25
9	6.92	4.70	5.70	4.15	3.95	3.28		2.78	3.93	3.33
12	5.88	6.03	4.00	3.70	3.03	4.60		4.58	2.95	3.30
13	6.12	6.68	5.63	3.57	3.35	4.00		2.88	2.83	2.88
14	7.52	7.50	6.08	4.20	4.50	2.58		3.65	4.68	4.30
20	6.36	4.20	5.83	3.55	3.88	2.58		2.20	2.83	3.08
27	6.64	7.43	4.55	2.98	4.40	3.93		3.25	5.40	4.70
			Lot No. 3 - Wheat Plus KCl							
8	6.40	3.65	3.43	3.25	4.43	2.33	2.25	4.55	4.55	4.58
16	5.60	3.60	3.68	2.95	3.50	2.23	2.58	4.70	3.55	3.70
17	6.92	4.55	3.83	2.90	4.18	2.30	2.65	4.65	2.95	3.20
22	4.88	3.75	3.48	3.38	3.08	2.83	3.78	4.30	3.95	3.75
25	8.08	5.80	5.45	4.35	4.05	2.95	3.95	5.63	5.00	4.68
29	6.48	6.15	3.75	3.43	3.55	3.78	3.10	4.33	4.33	3.50
31	3.88	4.80	3.58	2.18	2.85	2.08	2.08	2.08	3.20	3.78
32	6.12	4.38	4.75	3.40	3.63	3.10	3.60	2.83	4.55	3.43
35	6.48	4.75	3.08	3.40	3.45	2.93	2.78	2.20	3.35	3.30
36	6.48	5.20	3.45	2.85	3.48	2.85	3.45	3.50	3.05	3.40
			Lot No. 4 - Wheat Pasture							
5	6.60	5.35	2.90	2.92	3.35	3.00	5.00	2.58	3.88	3.43
7	5.68	5.80	4.70	4.97	5.25	4.00	5.17	4.30	4.25	3.93
11	6.32	4.38	3.95	2.80	3.78	2.55	2.85	3.30	3.43	2.83
15	5.12	3.70	2.80	2.52	2.83	2.63	2.65	2.20	3.70	3.75
23	5.20	4.08	3.43	3.35	3.18	2.39	2.55	3.18	3.35	2.83
24	6.00	5.43	5.40	3.08	3.05	2.83	3.08	3.98	3.33	2.68
26	7.96	5.38	5.45	3.75	4.45	3.80	4.32	4.08	2.80	4.75
30	5.32	5.50	2.90	2.93	3.43	2.28	2.92	2.45	3.53	3.63
37	5.52	5.20	4.05	2.80	3.38	3.00	2.55	3.85	4.05	3.05
39	7.64	5.33	3.60	3.05	3.63	3.55	2.95	2.95	3.60	2.80

K Composition of Sheep Plasma (mg. %)

Animal No.	1951 Oct.	Nov.	Dec.	1952 Jan.	Feb.	Mar.	Apr. 20	May 12	May 24	June
			Lot No. 1 - Dry Lot Control							
6	18.3	21.6	21.1	21.1	16.9	25.0		21.8	22.6	22.3
18	22.6	19.3	19.8	24.0	18.3	20.7		17.5	20.7	21.3
19	20.2	22.6	21.6	17.4	20.2	21.6		18.8	23.0	24.0
21	17.8	17.4	21.6	19.3	16.9	21.6		18.8	21.3	23.0
28	20.7	19.3	20.7	17.8	19.8	20.7		20.3	19.8	20.7
10	19.3	22.6	22.3	18.3	20.2	23.5		18.3	19.8	21.8
33	19.8	18.7	18.7	20.2	17.8	20.2		17.5	19.3	25.5
34	19.8	19.8	21.1	16.9	19.8	20.7		18.8	22.6	20.7
38	19.8	23.5	21.1	18.3	22.6	25.0		17.5	22.6	22.6
40	19.3	18.3	25.0	20.2	20.2	21.1		19.3	21.3	20.7
			Lot No. 2 - Dry Lot + KCl							
1	16.9	21.1	19.3	21.1	19.3	22.3		15.5	19.3	18.8
2	16.9	19.3	22.6	21.6	22.6	24.5		19.8	18.3	22.6
3	17.8	18.3	19.8	19.8	21.1	21.6		19.3	19.8	19.3
4	17.8	23.5	23.5	24.5	19.3	24.0		17.8	20.7	21.3
9	18.3	22.9	21.6	22.6	21.6	24.0		20.3	22.6	21.8
12	17.4	19.8	21.1	21.1	17.4	23.0		19.3	21.3	21.3
13	18.7	21.6	17.8	24.0	18.3	21.6		21.8	19.8	24.0
14	21.6	23.5	25.5	22.3	24.0	23.5		17.8	21.3	21.8
20	18.3	19.8	26.0	23.0	20.2	22.6		20.3	21.8	20.7
27	17.8	20.2	24.5	22.3	20.2	20.7		20.3	20.7	21.8
			Lot No. 3 - Wheat Plus KCl							
8	19.3	18.7	22.3	19.8	14.5	21.6	25.5	16.0	17.8	18.3
16	17.8	20.2	21.1	21.6	20.7	20.2	23.0	22.3	25.5	19.3
17	17.8	19.3	20.7	20.7	18.3	21.1	23.5	22.3	20.3	22.3
22	18.3	19.8	19.3	19.8	17.4	23.5	25.5	19.8	19.8	20.7
25	21.1	19.8	21.6	19.8	18.3	17.8	20.2	20.3	18.8	17.8
29	20.7	21.6	17.8	18.7	18.3	16.9	22.3	18.3	21.8	20.7
31	18.7	19.8	20.2	18.7	17.8	21.6	21.1	20.3	21.3	21.3
32	19.8	18.7	21.6	17.8	19.3	19.8	21.6	19.8	20.3	19.8
35	17.4	18.3	19.3	21.1	17.8	24.0	23.0	20.8	20.3	22.6
36	18.3	20.2	19.3	20.7	20.7	23.0	22.6	21.3	23.5	23.5
			Lot No. 4 - Wheat Pasture							
5	18.3	20.7	18.7	21.6	15.9	25.5	22.6	19.3	18.3	20.7
7	16.9	20.7	24.0	23.5	23.0	21.6	25.0	20.8	19.3	20.3
11	18.3	17.4	18.7	19.3	16.9	21.6	21.1	18.3	19.3	18.8
15	19.3	16.4	19.8	20.7	16.4	17.8	21.6	18.8	20.3	20.3
23	19.3	18.3	19.8	24.0	19.3	19.3	23.0	18.3	18.8	19.3
24	20.2	19.3	26.0	21.1	17.4	20.7	22.6	19.8	20.7	22.6
26	21.6	21.1	23.0	21.6	20.7	23.5	21.6	28.8	19.3	23.0
30	18.3	17.8	19.3	18.3	16.9	23.0	20.7	22.3	21.8	21.3
37	20.7	18.7	18.3	24.0	16.4	25.0	24.0	16.0	19.8	19.3
39	21.6	20.2	21.1	26.0	19.8	25.5	25.0	26.5	25.5	24.5

Na Composition of Sheep Plasma (mg. %)

Animal	1951			1952						
No.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr. 20	May 12	May 24	June 6
			Lot No. 1 - Dry Lot Control							
6	310	299	315	293	299	315		315	325	293
18	315	325	275	320	299	293		304	310	315
19	310	320	299	320	299	288		310	325	310
21	320	315	299	299	283	304		320	320	315
28	315	299	304	315	293	299		320	315	325
10	304	315	304	315	299	299		310	293	320
33	304	310	293	315	304	293		310	304	325
34	315	310	293	315	299	310		304	320	304
38	310	320	304	310	310	293		313	293	288
40	320	315	310	304	315	304		215	310	293
			Lot No. 2 - Dry Lot + KCl							
1	315	320	273	304	320	293		320	310	304
2	335	320	315	310	320	283		318	304	299
3	293	315	273	299	325	304		320	283	293
4	310	325	310	310	310	293		315	299	299
9	293	299	283	315	299	304		320	304	293
12	299	310	299	310	293	288		310	315	310
13	310	320	315	320	310	304		325	299	315
14	299	320	293	310	304	283		335	304	268
20	299	310	320	325	299	283		310	293	293
27	310	325	293	335	299	288		310	320	288
			Lot No. 3 - Wheat Plus KCl							
8	299	293	299	304	275	293	315	330	304	299
16	320	304	288	293	304	288	310	325	304	315
17	299	310	304	304	288	299	310	304	299	299
22	320	310	310	335	275	283	320	315	310	293
25	310	299	299	299	293	288	315	320	304	293
29	330	275	320	320	275	288	304	315	310	320
31	310	320	288	310	320	283	325	304	293	325
32	330	330	310	315	304	293	315	320	315	288
35	304	315	315	299	320	299	330	315	320	299
36	310	299	275	293	315	293	320	325	315	304
			Lot No. 4 - Wheat Pasture							
5	304	310	299	304	304	283	310	310	310	299
7	293	320	310	330	304	288	320	330	315	288
11	299	330	299	342	275	293	304	310	293	315
15	293	299	304	304	325	275	320	293	315	310
23	330	299	304	315	288	283	315	304	315	315
24	325	310	299	342	288	299	293	325	304	310
26	325	304	304	288	310	293	310	315	310	315
30	299	325	304	293	293	288	310	310	310	304
37	304	310	299	320	310	293	315	335	320	310
39	315	330	320	275	315	320	310	310	315	304

Record of Rabbit Weights (in grams)

Rabbit No.		Initial	1st	2nd	3rd	4th	5th	6th	7th
					End of Week				
Lot I	1	1622	1671	1765	1640	2005	2045	2230	2385
	2	1544	1482	1715	1655	2055	2090	2350	2495
	X-11	1828	1871	2125	2035	2470	2585	2870	2880
	X-13	1893	2006	2190	2205	2540	2690	2985	2000
Lot II	3	1676	1542	1690	1575	2060	2355	2630	2675
	4	1405	1504	1590	1540	2080	2235	2395	2515
	5	1801	2006	2095	1970	2565	2845	2900	3140
	X-133	1899	1964	1970	1925	2325	2545	2630	2805
Lot III	6	1483	1668	1845	1740	2265	2395	2625	2955
	7	1497	1708	1825	1795	2250	2390	2505	2760
	8	1466	1645	1875	1655	2140	2365	2435	2495
	X-12	1544	1633	1710	1610	2025	1925	2235	2445
Lot IV	9	1363	1533	1700	1540	1950	2130	2305	2340
	10	1477	1627	1775	1610	2180	2360	2580	2635
	11	1352	1562	1760	1680	2215	2510	2600	2690
	X-10	1630	1681	1860	1730	2125	2305	2435	2610
Lot V	12	1556	1663	1775	1625	1930	2115	2335	2285
	X-101	1342	1381	1575	1525	2135	2385	2225	1670
	X-102	1530	1721	1805	1760	2190	2485	2690	2690
	Y1-X10	1481	1673	1710	1605	2055	2185	2280	2395

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Thesis: THE EFFECT OF HIGH POTASSIUM INTAKE ON SHEEP AND RABBITS

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THESIS TITLE: THE EFFECT OF HIGH POTASSIUM INTAKE ON SHEEP AND RABBITS

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