STUDIES ON THE ETIOLOGY OF WHEAT PASTURE POISONING

By

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PREFACE

With losses up to one million dollars occurring in good grazing years from cattle grazing wheat pasturage the problem of wheat pasture poisoning assumes a major role in the economy of this nation.

The investigations of many workers have failed to solve the cause(s) of this disorder. In spite of this inability, work continues in the hope that this mystery will some day be revealed.

The investigations herein carried out attempted to produce the syndrome in two different ways without success. It was learned, however, that a ration simulating the young wheat plant affects the metabolism of magnesium.

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INTRODUCTION

In the Southern Great Plains it has become a standard practice for cattle to be grazed on winter wheat pasture during the winter and early spring months. Studies begun in 1926 at the Kansas State Agricultural Experimental Station indicated that the growing wheat plant is very nutritious and that the grazing is not harmful to the wheat plant (1). Farmers consider wheat to be a very good winter pasturage (2) from which they can derive additional income, either in money saved on feed or in money earned by renting their wheat pasturage (3). At the Amarillo station from 1943 to 1949, studies conducted on the year-round grazing of various native grasses and winter wheat indicated that wheat is a good fall and winter pasturage (4).

Losses, however, occasionally occur from grazing cattle on wheat, some due to bloat and some to "poisoning" (1). The bloat occurs when cattle graze wheat that has frost or heavy dew on it (5) and can be prevented by not turning the cattle onto it until the moisture is gone. The "poisoning" is not due to any known toxic compound(s) in the wheat plant although the young, fast-growing wheat plants on well-fertilized pastures are suspected to contain a mineral imbalance or toxic products which would cause the syndrome (6). The soil type and/or soil fertility may be a cause of such imbalances (7). The high potassium content of the growing wheat plant has been suggested as a causative factor (8,9). The young wheat plant also is very high in nitrogen (10), and this may contribute to some type of abnormal ruminal function. The disorder may be a complicated nutritional-physiological disturbance (2).

The disease does not appear to be due to a mineral-deficient diet (6,9,11), although Bourne says calcium and magnesium are poorly absorbed from the intestines, especially at a neutral or alkaline pH. He believes that the low blood levels of these ions observed in cases of wheat pasture poisoning may be due to actual dietary deficiences, excessive withdrawals (of calcium by lactating animals, for example), endocrine factors, vitamin deficiencies, physical exhaustion, excitement, shipping, driving, and faulty management (12).

Wheat pasture poisoning usually affects lactating cows, 60 to 90 days after being turned on lush-growing wheat (3,13). It is believed the animals are more susceptible to the disorder after grazing on poor summer pasture resulting from drought (2). The condition does not occur in cows only but also in sheep and horses (6,7,12,14) grazing rye, oats, barley, Austrian winter peas, Bermuda and other natural grasses (3,11,12, 14,15). The affected animal does not have to be lactating, as the syndrome has occurred in dry cows and steers (14,15,16,17,18), but the usual conditions are parturient animals grazing succulent pasturage (9,14,19). In sheep grazing oats in Mississippi, it usually occurs one to three weeks after parturition (7). The disorder usually occurs in the spring but has occurred in every season (11,16,20,21).

The symtoms of wheat pasture poisoning are nervousness, hyperexcitability, muscular inco-ordination, tetanic contrations of the limbs, drawing back of the head, gnashing of the teeth, rolling of the eyeballs, and frothing at the mouth (3,11,17,22). Analysis of the blood of the affected animals shows magnesium to be low; calcium may or may not be low (3,6,7,11,12,17,18,20,23,24,25). There is also a lowering of the blood sugar (3,26). If the animal is excited or exercised involuntarily the tetanic symptoms may be intensified (3,12,16).

This syndrome is not to be confused with milk fever, with which it is very similar (21,27) nor with other similar diseases (13,21). In wheat pasture poisoning the blood contains low magnesium and possibly low calcium, whereas in milk fever the blood magnesium is normal or high and the blood calcium and phosphorus are low (2,12,17,28).

Wheat pasture poisoning has been linked with grass tetany and the great similarity between them leads one to the conclusion that they are the same syndrome. Grass tetany has been known in Holland since 1907 (25) although the first description of it did not appear until 1929 (27). Since that time much has been written about it but as yet its cause(s) remain unknown (21,22,29,30,31). Although wheat pasture poisoning in the Southern Great Plains is associated with beef cattle, elsewhere the work has been almost exclusively with dairy cattle and the name lactation tetany has been used, especially in Great Britain (28).

Earlier work had been done on magnesium deficiency but not until Kruse and his workers conducted their extensive experiments on the subject was a actual need for it shown (32,33,34,35,36,37,38). Dryerre said that magnesium and calcium are physiologically antagonistic to one another in their action on the nervous system. Magnesium inhibits and calcium stimulates nervous activity. Magnesium is needed for efficient functioning of the heat controlling center, and the calcium to magnesium ration determines the excitability of the neuro-muscular mechanism (39). It has been found that magnesium deficiency manifests itself locally by hyperirritability and constitutionally by nutritive failure (34). Low blood magnesium causes nervous excitability while low calcium and high potassium result in unconsciousness (3).

Greenburg and Tufts found a sharp decrease in plasma magnesium and then a rise to a peak after the onset of hyperexcitability. It fell again during the second phase but not to as low a level. They believed that the reduction in the plasma magnesium is not directly responsible for the condition of hyperirritability (40). In a diet containing normal calcium, five milligrams of magnesium per one hundred grams of food was the borderline level required for good growth. A high calcium content in food increased the severity of magnesium deficiency and raised the amount necessary to meet the minimum magnesium requirements. They found no direct relationship between riboflavin and the malnutrition due to magnesium deficiency (41).

Duncan et al. conducted experiments with calves fed milk, which is low in magnesium, and found that they developed tetany (23). Further work revealed the possibility that milk may be deficient in some factor necessary for normal magnesium metabolism (42).

Diets containing various levels of magnesium have also been studied. Cunningham found that magnesium added as the phosphate had no harmful effect on the bone composition, but if given as the sulphate or carbonate, there resulted a lowered ash content of the bone (with the calcium content lower and the magnesium increased). He also found that the serum magnesium appeared to be directly related to the magnesium content of the diet (43,44).

A study of the magnesium content of pasture samples taken at monthly intervals for a year showed that a dietary deficiency of magnesium was not the cause of grass tetany (45). Duncan et al. studied the blood of calves in their early life and found a gradual rise in the magnesium content (46). Allcroft studied the blood of cows before and after calving and that of the calves after birth and found a decrease in serum calcium and inorganic phosphorus prior to parturition which rose after birth to near its former level. The serum magnesium changed little. No significant difference in the blood composition of the calves was noted (47). Barker studied the changes in the blood of cows and believed there might be a relationship between the blood magnesium and the climatic conditions prevailing in June of any one year (48). Upon regrouping their data, Duncan et al. showed that there was a decrease in the blood magnesium of calves from January to July and an increase from July to January (49).

Since Bourne suggested that poor absorption of magnesium was responsible (12), a study of the availability of magnesium was deemed advisable and was conducted. The result of the study showed 63-74% of the magnesium found in fresh grass was retained by cattle. Garner concluded that the amount of magnesium retained is not apparently dependent on magnesium, calcium to phosphorus ratio , or the crude fiber content of the food (50).

In 1938 Duckworth wrote an excellent review on the role of magnesium in the animal body (51) and a more recent review was written by Russell (52).

Of possible etiological significance in wheat pasture posisoning is the magnesium to calcium ratio in the blood plasma, which is 1/3.5 in normal and 1/14 in affected cattle (3). In grass tetany Sjollema found the Ca/Mg to be 14, in milk fever it was 2, and in normal cattle it was 6 (53).

The workers in Oregon and Kentucky found that cattle could have a lowered blood magnesium, up to one-half of the normal value, without developing symptoms of grass tetany, but when the blood calcium was also lowered the symptoms did develop (11,17).

Caldwell and Hughes believe an imbalance between the mono- and divalent ions in the nerve tissue is responsible for the symptoms of grass tetany. It is known that muscular action, causing an increase in potassium in the blood from the muscles, upsets the mineral balance of the nerve tissue. If the balance has been shifted in the direction of too much monovalent element in proportion to the divalent element, then muscular exercises might push the balance farther from normal, possibly resulting in tetany. Elevation of tissue potassium causes hyperirritability. The amount of sodium and calcium in the tissue is small compared to the amount of each in the blood, whereas the amount of potassium and magnesium in the tissue is greater compared to the blood content of each (16). Experiments were conducted on the effect of varying amounts of potassium. It was found that when the blood potassium to calcium ratio was 2.62 or larger the animals exhibited symptoms of grass tetany (22,54). Potassium could interfer with the utilization or metabolism of calcium or magnesium (9) although experiments with rats showed that high potassium had little or no effect on the blood magnesium (8,9).

The growth rate of rats was depressed when potassium as the bicarbonate furnished 5% K in the diet. Using the carbonate to furnish 3% K produced similar results, but when this was increased to 5% K it resulted in a high mortality. By increasing the magnesium of the high potassium diet the mortality was reduced with little effect on the rate of gain (8). Experiments conducted with sheep on a ration containing 5% K as the bicarbonate had no significant effect on the serum calcium, magnesium, or potassium (9).

Rats on a potassium deficient diet had a slow loss in weight, short fur-like hair, cyanosis, abdominal distention, and lethargy leading to coma and death. When on a magnesium deficient diet the rats showed a subnormal growth in the early part of the experiment with part of their gain lost before death came. Early hyperirritability led to tonic convulsions and often to death. When both magnesium and potassium were deficient in the diet the sympomatology and pathology were similar to those of the potassium deficient diet except that the rats showed the early hyperirritability of the magnesium deficiency. Normal levels of both elements showed no abnormalities except a subnormal rate of growth (55).

Smith treated dogs with $MgSO_4$ and showed a serum potassium decrease with the increase in the serum magnesium (56). She later repeated the treatment and showed the same effect with normal serum sodium and calcium. When KCl was injected with the $MgSO_4$ the serum magnesium tended to be decreased (57).

Various amounts of potassium and calcium were given to sheep and no blood potassium or calcium differences were noted. A ration containing mixed alfalfa-grass hay (1.31% K and 1.60% Ca) showed a greater retention of calcium than did a ration containing 2.73% K and .61% Ca or one with 4% K and .61% Ca, whereas the ration with 4% K and 1.60% Ca showed a decrease in calcium retention (58).

When high levels of either or both calcium and potassium were fed rats, there was a hastening of magnesium deficiency by three to four days. High calcium increased the mortality rates, high potassium depressed the growth, and a diet high in both elements increased the mortality, decreased the growth, and lowered the blood magnesium (14).

Daniel et al. found that the blood magnesium of sheep on a diet of wheat pasture and wheat pasture plus $CaCl_2$ tended to decrease, whereas added potassium produced no significant change (59). Kunkel et al. found a lowered serum magnesium in sheep on a ration containing 5% K as the bicarbonate without any clinical symptoms (60).

Sjollema found that adding protein in the form of earthnut meal caused a decrease in the serum calcium, a definite fall in the magnesium, and a variable change in the inorganic phosphorus. But when he used soya and wheat gluten no such effect was produced (61). Experiments with rats fed an increased level of protein showed an increase in magnesium deficiency. The blood magnesium was lowered when the rats were fed normal protein, high potassium, and high calcium. A ration high in protein and in calcium failed to show a further decrease in the magnesium deficiency (10).

Barrentine showed there was a greater susceptibility to develop tetany in parturient or post-partum animals when grazing short oats (this being oats grazed to a height of two inches by nonexperimental animals) (62). He feels the low blood magnesium is not due to a low dietary magnesium as oats and wheat have as much as any forage, but that there is too much protein in the forage for ruminants. He suggests that protein is broken down to ammonia in the rumen and that in the small intestine this combines with magnesium and phosphate to form the very insoluble salt, $MgNH_4PO_4 \cdot 6H_2O$. Calcium would also be lost in this way. The reason legumes, which are also high in protein, do not cause tetany is because there is enough calcium present to tie up the excess ammonia (62).

Broersma feels grass tetany is due to poisoning and makes much of the fact that the condition occurs most often where artificial manures have recently been applied (63,64). Recent work with the effects of fertilizer show that grass fertilized with ammonium sulphate caused a lowering of the blood magnesium and grass tetany did develop in some animals grazing this grass. Some evidence of lowered serum magnesium due to potash fertilization is also presented (65).

Brouwer found that animals grazing pastures having a base excess (K + Na + Ca + Mg - Cl - S - P) but a negative alkali alkalinity (K + Na - Cl - S) had an acid urine, a condition he feels is not desirable. Grass from tetany-inducing pastures was found to have a high alkali alkalinity (K + Na - Cl - S) and a low alkaline earth alkalinity (Ca + Mg - P), whereas poor quality herbage was just the opposite. The variations in alkali and alkaline earth alkalinity appear to be related mainly to the potassium content (66).

Green, addressing a veterinary meeting in 1939, said that there was some definite nervous or endocrine control for magnesium metabolism, although this was disputed by a member of his audience (67). Several Italian workers have studied the hormonal effect on magnesium levels of the blood and on its metabolism. The anterior lobe of the pituitary appears to control magnesium levels in some fashion (68,69,70,71,72,73).

In view of the apparent success of the short-grazed method of inducing tetany and the possible effect of fertilization, it was decided in 1953 to graze sheep and cattle on fertilized and unfertilized "short" oats and wheat during the spring of 1954, in an attempt to produce grass tetany. As the young wheat plant is high in protein and potassium and low in sodium, an attempt was also made to see what effect a ration approaching the mineral and protein content of the growing wheat plant would have on sheep. Experiments have been conducted with rations high in potassium or in protein but none have been conducted where both were high simultaneously, the condition existing in succulent wheat pasture.

I. THE EFFECT OF FERTILIZING WHEAT AND OATS ON THE OCCURRENCE OF WHEAT PASTURE POISONING

EXPERIMENTAL PROCEDURE

Several paddocks of wheat and oats were prepared at the Panhandle A. and M. College in Goodwell, Oklahoma. Ammonium nitrate was applied to the fertilized plots; the other plots were not fertilized. After the wheat had grown and was at a good grazing height, sheep were placed on the paddocks to graze them down to a height of 1-1/2 to 2 inches. The experimental animals (both sheep and cattle), meanwhile, were fed in dry lot until the time for them to be placed on the short-grazed wheat. They were bled on the day they were placed on pasture and on the 2, 3, 5, 7, 10, and 15 days thereafter. This was done in order to detect any changes in the blood composition which might occur in the first few days after going on pasture.

In Trial I two cows were placed on fertilized, short-grazed wheat and two on unfertilized, short-grazed wheat. Four ewes were handled in the same manner. All cows and ewes were nursing young.

In Trial II five cows were placed on fertilized, short-grazed oats. No unfertilized control was available at that time. They were bled daily for one week.

Blood was collected in heavy-wall, 20 x 180 mm tubes treated with lithium citrate, this being the best anticoagulant when a variety of mineral analyses are to be run on the same blood sample (74). They were prepared in the following manner. A solution was prepared containing 114 grams of lithium citrate per liter. Two milliliters of this solution were placed in each tube to be citrated. The tubes were then placed on a hot plate to evaporate the water. When this was done the lithium citrate puffed up into a white, shiny, cellular structure which was instantly soluble in blood. If heated too much the carbonate would be formed and the solid would be dull in appearance. The citrated tubes, after being cooled and corked, can be stored for later use or transported to another destination without loss of the anticoagulant.

Several tubes prepared in this manner were sent to Goodwell for the use of the workers there. After withdrawing the blood samples, they were centrifuged, the plasma separated, stored under refrigeration, and sent to Stillwater for analysis.

Plasma calcium was determined by precipitation as the oxalate followed by titrating with .01 N $KMnO_4$, the method being essentially the Clark and Collip (75) modification of the Tisdall method (76).

Plasma inorganic phosphorus was determined colorimetrically with ammonium molybdate and aminonaphtholsulfonic acid according to the method by Fiske and Subarrow (77).

Magnesium of the blood plasma was determined colorimetrically with titan yellow, using polyvinyl alcohol as the stabilizer; this is mainly the method of Garner (78).

The methods used at this laboratory for the determination of these constituents in blood are described in detail by Shrewsberry (79).

RESULTS AND DISCUSSION

The animals on the paddocks in this investigation showed no signs whatever of wheat pasture poisoning. No tonic-clonic convulsions, nervousness, hyperirritability, muscular inco-ordination, drawing back of the head, gnashing of the teeth, protruding eyes, nor any other symptoms of the disorder were observed. To all appearances the animals were quite healthy.

Figure 1 presents a graphic representation of the average plasma magnesium values for cattle during the period the animals were grazing the wheat pasture. Individual values can be found in the appendix tables. As the graph shows, the plasma magnesium values for the cattle on the fertilized, short-grazed wheat fell for a period of ten days and then leveled off at the lower value of 1.4 mg%. Blood magnesium levels of cattle on unfertilized short-grazed wheat decreased somewhat but did not decline below 1.9 mg%. This decrease was followed by a return to normal values by the 15th day. The results for the sheep were inconclusive. The plasma magnesium values presented a variable picture with a slight decline for the sheep on fertilized, short-grazed wheat, whereas the sheep on the unfertilized, short-grazed wheat had plasma magnesium values which rose, fell, rose, and fell again but remained above 2.0 mg% which would be within the normal range of values (Figure 2).

The plasma calcium values were within the normal range, with the cows on the fertilized pasturage having the highest values (Figure 3) and no apparent difference in the plasma values of sheep (Figure 4).

The plasma inorganic phosphorus (Figure 5) of both the cows on the

Figure 1. Levels of Blood Plasma Magnesium of Cows Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.

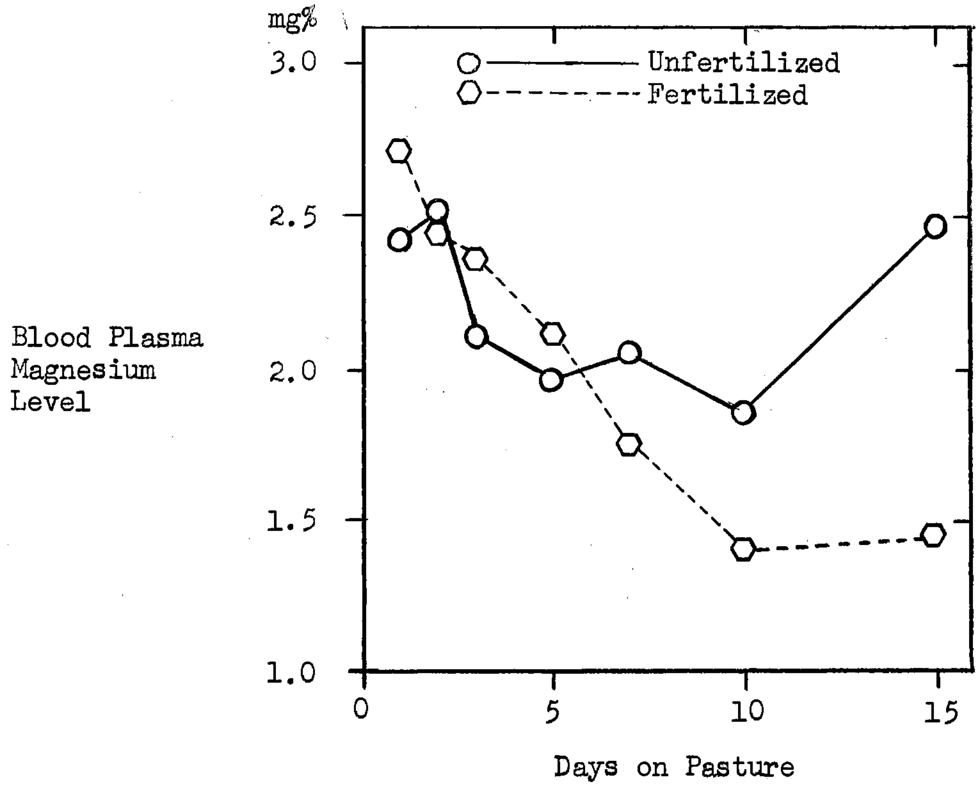


Figure 2. Levels of Blood Plasma Magnesium of Sheep Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.

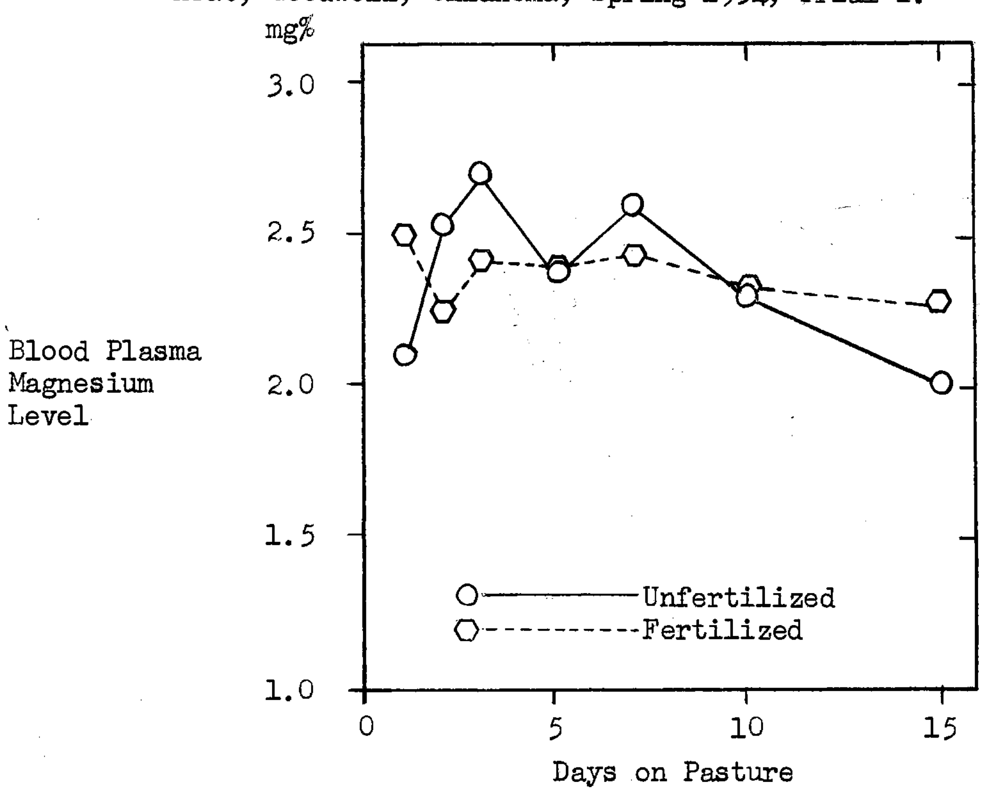


Figure 3. Levels of Blood Plasma Calcium of Cows Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.

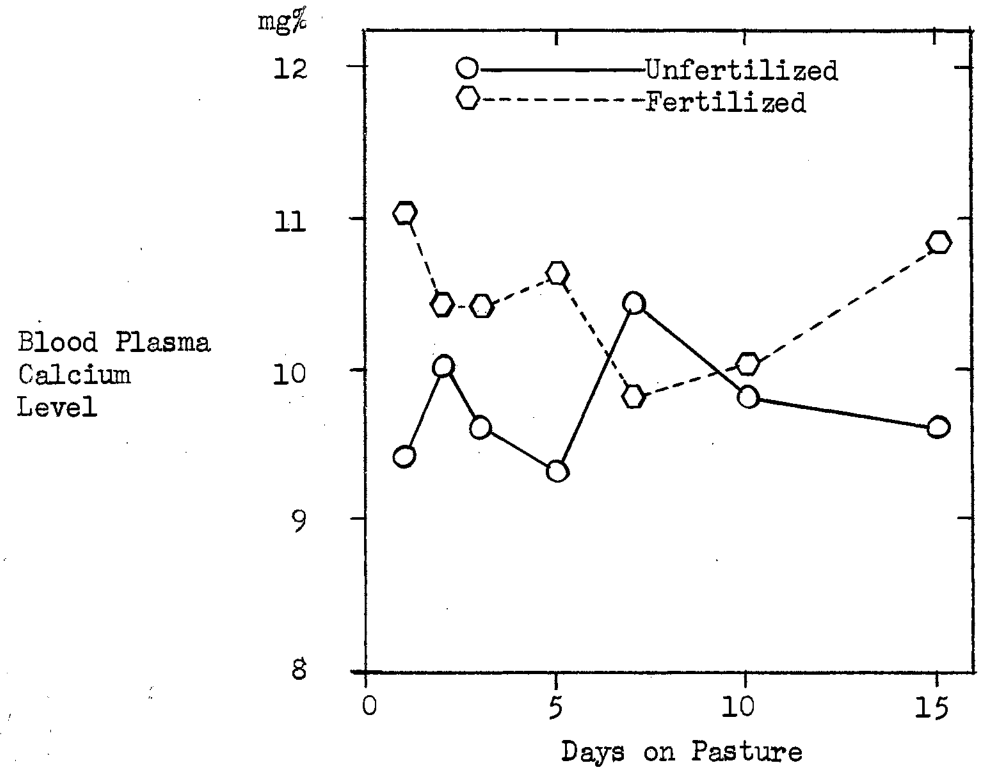


Figure 4. Levels of Blood Plasma Calcium of Sheep Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.

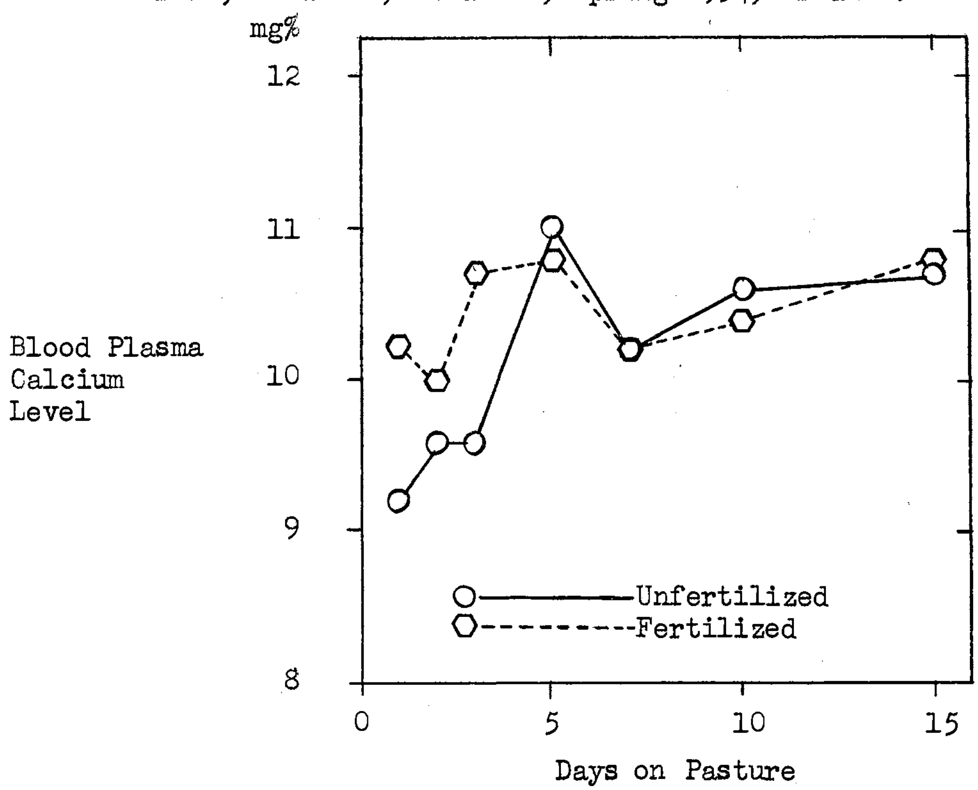


Figure 5. Levels of Blood Plasma Inorganic Phosphorus of Cows Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.

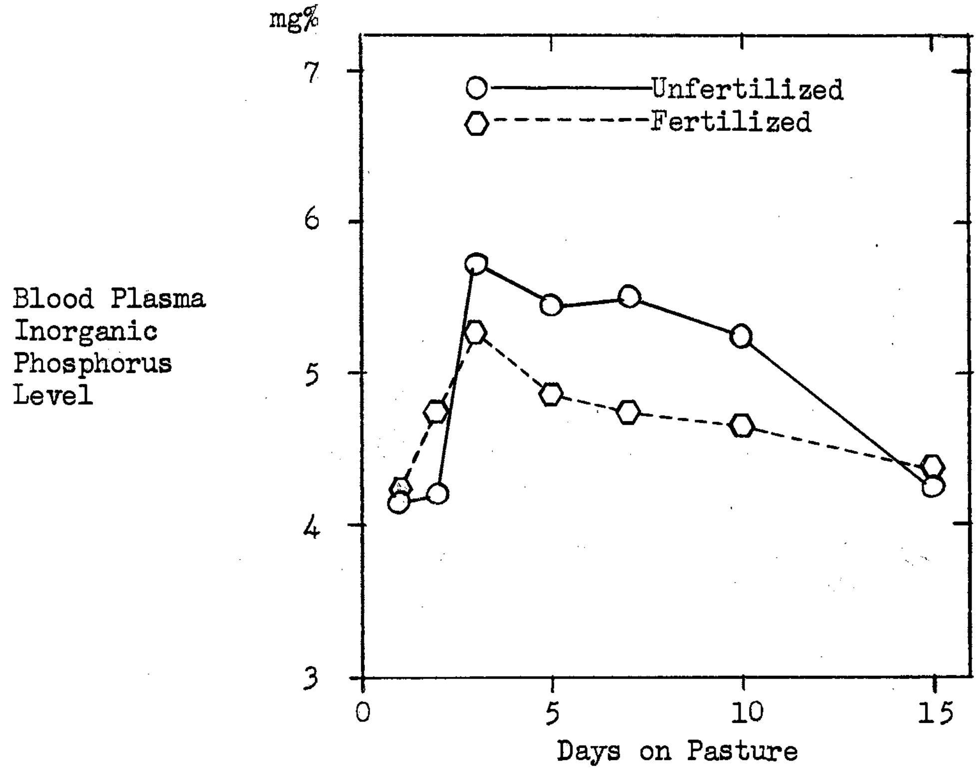
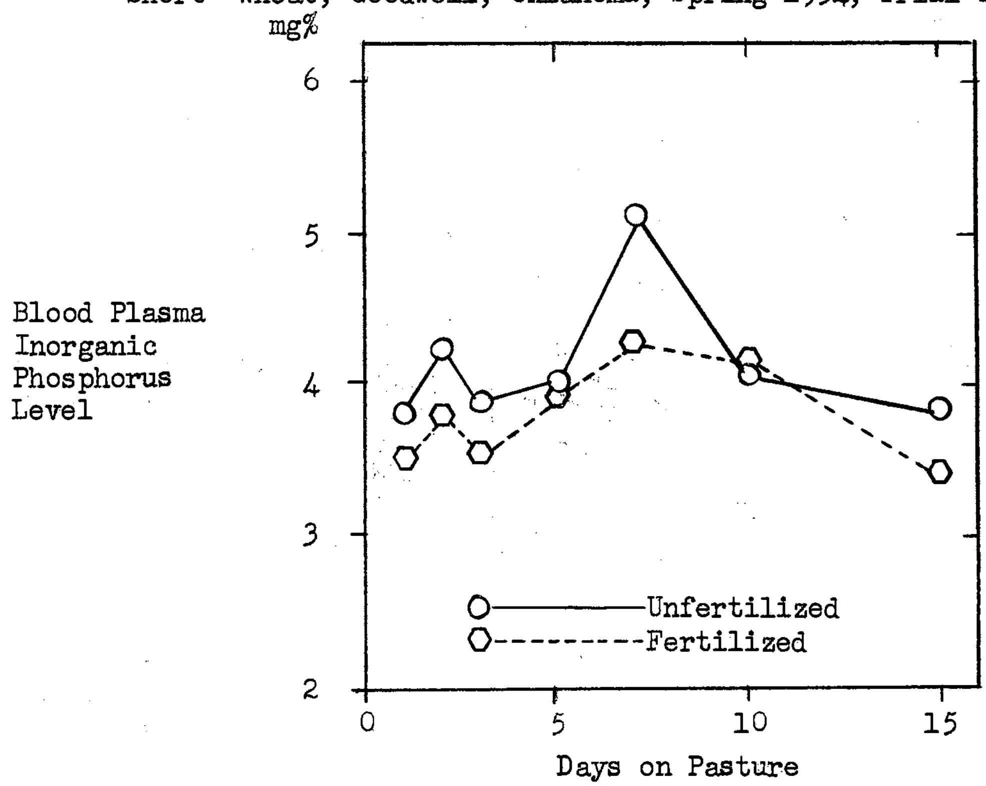


Figure 6. Levels of Blood Plasma Inorganic Phosphorus of Sheep Grazing "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I.



fertilized and the unfertilized paddocks showed a rapid rise and a gradual decrease to the starting value. The cows on the fertilized, short-grazed wheat had the lower values throughout most of the trial. The inorganic phosphorus values for plasma of sheep, as shown in Figure 6, present a somewhat different picture. Here again, the phosphorus values for the animals on the fertilized paddocks are lower than for those on the unfertilized plots. There was a rise in the plasma inorganic phosphorus values occurring in the middle of the trial which was common to both groups but the sheep on the fertilized pasturage did not have as high an increase.

Table I gives the summary data of the cattle on the fertilized, short-grazed oats in Trial II. The blood plasma showed a rise, fall and rise in magnesium for the seven days, the calcium remained essentially the same, and the phosphorus fell on the first day but rose to a very high value (8.53 mg%) on the second day and declined steadily to almost half that value on the last day.

Table I. The Average Blood Plasma Values of Magnesium, Calcium, and Inorganic Phosphorus of Cows on Fertilized Oats. Trial II, 1954.

Day Bled		before	1	2	3	4	5	6
Magnesium	mg%	2.61	2.84	2.66	2.12	2.30	2.60	2.76
Calcium	mg%	9.4	8.8	9.8	9.9	9.2	9.2	9.1
Inorganic Phosphorus	mg%	6.68	6.23	8.53	8.07	6.58	5.61	4.81

SUMMARY

In the two trials conducted during the spring of 1954 on the effect of grazing cattle and sheep on fertilized and unfertilized, short-grazed wheat and oats, no symptoms of wheat pasture poisoning were produced. There was a lowered blood plasma magnesium of cows on the fertilized, short-grazed wheat. There was also a rise and fall in the inorganic phosphorus of the blood plasma of the animals on both types of pasturage, with the lower values being those of the animals on the fertilized paddocks. The plasma calcium values remained within normal limits with slight variations. The lowered plasma magnesium did not occur in the animals on the fertilized, short-grazed oats; however, the plasma inorganic phosphorus rose to a high value and then fell following the pattern of the animals in the first trial.

It would appear from this investigation that the only effect produced in the plasma composition of the blood of animals grazing fertilized, short-grazed wheat and oats was the lowered magnesium and the increase in inorganic phosphorus and its later decrease.

II. THE EFFECT OF HIGH PROTEIN, HIGH POTASSIUM INTAKE BY SHEEP ON RATION DIGESTIBILITY AND MINERAL METABOLISM

EXPERIMENTAL PROCEDURE

Several western wether lambs were obtained in January, 1955. They were brought to the Animal Husbandry arena of Oklahoma A. and M. College and fed and cared for. They were branded with paint and weighed. Twelve of the lambs were placed in metabolism stalls in a basement room of the Animal Husbandry building. The lambs were fed twice daily with access to all the water they would drink.

The sheep were divided at random into two groups of six animals each and then the groups were randomly selected to see which group received which ration. Two rations were prepared. One was compounded to contain the levels of protein, magnesium, calcium, phosphorus, and potassium usually found in sheep rations composed of natural materials. The other was compounded to simulate the nitrogen and mineral composition of the young wheat plant. Both rations were low in sodium. The components of each ration are shown in Table II. The chemical composition of the respective rations used in the various experiments and that of the young wheat plant are given in Table III.

Experiment 1.

The collection period for Experiment 1 was begun in the evening, February 6, 1955. Urine was collected in bottles containing 15 ml. of 1:1 H_2SO_4 and about 500 ml of water. Feces were collected in the pans provided. Daily samples were taken. The urine was made to 4000 gm and 200 ml of the diluted urine (or 5% of the sample, whichever was larger) was placed in sample bottles and stored in the refrigerator. The feces

Table II. Components of the Rations Used in the Spring, 1955 Experiments

	Ration I	Ration II
Experiment 1		
Alfalfa hay	301 gm	301 gm
$KHCO_3$	----	62 gm
Concentrate mixture	368 gm	368 gm
(Yellow corn)	(32.73%)	(32.73%)
(Drackett protein)	(5.45%)	(62.44%)
(Cerelose)	(59.27%)	(----)
(KH_2PO_4)	(2.31%)	(----)
($CaCO_3$)	(.14%)	(----)
($MgSO_4$)	(.09%)	(----)
($KHCO_3$)	(----)	(1.22%)
(DL-Methionine)	(----)	(3.62%)
Experiment 2, Trial I		
Alfalfa hay	198 gm	198 gm
$KHCO_3$	----	34 gm
Karo syrup	40 gm	40 gm
Concentrate mixture	202 gm	202 gm
(Same as in Exp. 1)		
Experiment 2, Trial II		
Alfalfa hay	234 gm	234 gm
$KHCO_3$	----	47 gm
Karo syrup	40 gm	40 gm
Concentrate mixture	246 gm	247 gm
(Yellow corn)	(32.73%)	(32.73%)
(Drackett protein)	(5.45%)	(62.44%)
(Cerelose)	(59.54%)	(----)
(KH_2PO_4)	(2.27%)	(----)
($KHCO_3$)	(----)	(1.45%)
(DL-Methionine)	(----)	(3.38%)

Table III. Chemical Composition of the Rations of the Spring, 1955 Experiments and of the Young Wheat Plant in Percent.

	Dry Matter	Dry Matter Composition								
		Organic Matter	Ash	Protein	N	Ca	Mg	P	Na	K
Ration I										
Exp. 1	90.68	94.60	5.40	13.02	2.08	.66	.19	.52	.05	1.50
Exp. 2, Trial I	90.68	95.01	4.99	12.61	2.02	.68	.24	.45	.06	1.32
Exp. 2, Trial II	89.21	94.81	5.19	12.46	1.99	.63	.19	.48	.04	1.42
Ration II										
Exp. 1	91.40	88.28	11.72	39.23	6.28	.61	.18	.43	.08	5.07
Exp. 2, Trial I	91.42	89.73	10.27	32.85	5.26	.63	.22	.39	.08	4.34
Exp. 2, Trial II	90.52	88.67	11.33	34.99	5.60	.59	.19	.44	.07	4.99
Wheat[1]	92.98	87.25	12.75	29.75	4.76	.40	.16	.46	.03	4.51
Wheat[2]	96.85	82.57	17.43	29.69	4.75	.62	.30	.41	.08	5.55

[1] Data obtained from Shrewsberry (79).
[2] Data obtained from the work of Gibson at this laboratory.

were dried overnight in an oven at 60°C., removed, and allowed to come to air dryness. The orts were weighed and kept in suitable containers.

The experiment was continued for only five days because of the large feed refusals. A defective oven caused the fecal collections for the fourth day to be destroyed. Because of this, all collections for this day were thrown away.

The daily collections were pooled at the end of the experiment and aliquots were taken for analysis, except for the feces, all of which was saved. The feed, orts, and feces were ground in the Wiley mill, thoroughly mixed, sampled, and placed in sample bottles.

Experiment 2.

The second experiment was divided into two trials, with Karo syrup being added to both rations to make them more palatable. The preliminary period of Trial I was begun on the evening of March 2, 1955, and the collection period began the morning of March 13. The urine and feces were collected as described before, the urine being made to 5000 grams from which 150 milliliters or 3%, whichever was the larger, was taken and stored in the refrigerator. The composition of the rations was the same as that used in Experiment 1 except for the added Karo syrup. The collection period was stopped at the end of ten days. The total orts, feed, feces, and urine samples for the ten day period were sampled; all but the urine and Karo syrup samples were ground in the Wiley mill, mixed thoroughly, and aliquots kept in sample bottles.

The preliminary period of Trial II was begun April 3, 1955 and the collection period was started April 13. The urine and feces were collected as before. The period of collection was ten days. The rations for this trial were altered slightly from the previous trials, in an attempt to more nearly equalize the mineral content of each ration. All solid samples were ground and aliquoted as before. The sheep were removed from the metabolism stalls and weighed. The weights of each before and after the experiments are shown in Table IV.

Table IV. Weights of Lambs Before and After the Balance Studies.

Diet	Sheep no.	Jan. 15, 1955	Apr. 25, 1955
Ration I	3	68 lbs.	74 lbs.
	8	69	73
	9	55	62
	12	79	77
	13	68	72
	15	62	67
Average		67 lbs.	71 lbs.
Ration II	4	67	65
	5	70	71
	6	67	73
	7	63	66
	10	58	68
	11[1]	72	--
	14	72	70
Average		66 lbs.	69 lbs.

[1]Not included in average.

Blood samples were taken periodically throughout both experiments to be analyzed for magnesium, calcium, phosphorus, sodium, and potassium. The plasma magnesium, calcium, and inorganic phosphorus were determined as described in the first section. Plasma sodium and potassium were analyzed by the direct method on the Perkin-Elmer Flame Photometer, Model 52-C. A lithium salt had been added to the blood to prevent coagulation, and it was thought the internal standard method could not be used. Since the analyses were completed, a check into the concentration of the added lithium to the blood and what it would be in the sample analyzed has shown 30 ppm of lithium to be present. In the internal standard method a concentration of 1000 ppm of lithium is used. Whether or not the 30 ppm present in the plasma sample to be analyzed would affect the internal standard method should be investigated. The direct method has some serious limitations when applied to flame photometry and it is believed that greater precision can be attained using lithium as an internal standard.

One ml of blood plasma was diluted to 25 ml and this solution was used for analysis of both sodium and potassium by the direct method as described in the Perkin-Elmer manual (80).

A weighed amount of each of the feed, orts, and feces samples were analyzed for moisture and ash. The sample was dried overnight in an oven at 100° C. for moisture and heated overnight in the muffle furnace at 600° C. for ash. The ash was then transferred to 250-milliliter beakers, five ml of concentrated HCl was added, and all the beakers were placed on the steam plate to dehydrate the silica. After going to dryness, they were removed, cooled, and three ml of concentrated HCl and about 150 ml of water was added to each. They were placed again on the steam plate, heated for an hour, filtered into 250 milliliter volumetric flasks with washings, and allowed to cool. When cool they were made to volume, thoroughly mixed, and transferred to stoppered, 250-milliliter Erlenmeyer flasks for storage.

An aliquot portion (50 ml) of each of the urine samples was placed into a 150-milliliter beaker, five ml of concentrated H_2SO_4 was added and the samples were placed on the steam plate to remove all water. Hydrogen peroxide was added to each sample to oxidize the organic matter. When the oxidation was complete, water was added, heated, and the solutions were quantitatively transferred to 100-milliliter volumetric flasks. Five ml of a lithium nitrate solution were added to each flask and made to volume with distilled water, thoroughly mixed, and quantitatively transferred to 125-milliliter Erlenmeyer flasks. The lithium nitrate solution contained 20,000 ppm of lithium, thus giving a final concentration of 1000 ppm in the solution. The urine samples were then ready to be read by the internal standard method on the Flame Photometer for sodium and potassium.

All samples (feed, orts, feces, and urine) were analyzed for nitrogen, magnesium, calcium, phosphorus, sodium, and potassium.

Nitrogen was determined by the standard Kjeldahl method of analysis. Protein was determined on the solid samples by multiplying the nitrogen content by 6.25.

The mineral analyses were conducted on the solutions prepared as described above, aliquot portions being taken.

Fifty ml of the ash solution (including the urine solutions) were pipetted into 250-milliliter beakers, five ml of a 10% oxalic acid solution (with added methyl red indicator) were added to each and water was added until the beaker was half full. They were placed on the steam plate until warm (about an hour); ammonium hyroxide was added until the solutions were neutralized (the "just pink" color) and then digested one hour. They were removed from the steam plate, covered and left to precipitate overnight. All samples were then filtered through Gooch filters with specially treated asbestos mats. They were thoroughly washed with water and the precipitate and asbestos mat of each was transferred back into the original beaker, fifty ml of 1:9 H_2SO_4 were added, heated, and titrated with .05 N $KMnO_4$. The amount of calcium was then calculated in each sample, suitable correction being made for the blank which was run with each group of analyses.

An aliquot portion (one to five ml) of the ash solution (including the urine solutions) was pipetted into a colorimeter tube, water was added until the volume was eight and one-half ml and then one ml of Molybdate I was added, immediately followed with one-half ml of aminonaphtholsulfonic acid. All tubes prepared thusly were well mixed, set aside for twenty minutes to allow the color to develop, and then read in the Evelyn colorimeter at 660 millimicrons. A standard curve was prepared and the unknown phosphorus values were calculated from it. Molybdate I contains 25 gm $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ and 500 ml of 10.0 N H_2SO_4 per liter of solution. Aminonaphtholsulfonic acid contains .5 gm of 1,2,4-aminonaphtholsulfonic acid, 195 ml 15% $Na_2S_2O_5$ and five ml 20% Na_2SO_3 per 200 ml of solution.

Sodium and potassium were determined by the internal standard method on the Flame Photometer as described in the manual (80).

In an effort to determine magnesium in feed, orts, feces, and urine as it was done for blood plasma, a search of the literature was conducted to find a method similar to the colorimetric one used. A method by Young and Gill (81) was modified for use in the determination of magnesium in these materials.

The following solutions were prepared and used.

Hydroxylamine hydrochloride, 1% (wt/vol)

Compensating solution, containing, per liter of solution:

1.2625 gm	$CaCO_3$
.1341 gm	$AlCl_3 \cdot 6H_2O$
.1874 gm	$MnCl_2 \cdot 4H_2O$
.7000 gm	$Na_3PO_4 \cdot 12H_2O$
.0590 gm	$CuSO_4 \cdot 5H_2O$
7 ml	HCl (concentrated)

Polyvinyl alcohol, containing 20 gm of medium viscosity polyvinyl alcohol (DuPont grade 71-24) per liter of solution.

Thiazole yellow, containing 20 mg thiazole yellow (General Aniline Works) per 100 ml of solution. This brand of thiazole yellow is used because of its purity. Although titan yellow and clayton yellow are the same thing as thiazole yellow, their purity is such that they are very poor color reagents for this procedure.

Sodium hydroxide, 10 N.

A mixed reagent was prepared just before use. It consisted of equal parts of hydroxylamine hydrochloride, compensating solution, and polyvinyl alcohol.

The samples used for analysis were the ash solutions (including urine) already described. A series of standards were prepared, ranging from 0.0 gamma to 25.0 gammas of magnesium, and read in the Evelyn colorimeter at 540 millimicrons. The resultant curve did not follow Beer's law so aliquot portions of the samples were taken which would read on the best part of the curve. All rubber connections, corks, etc., were avoided as rubber affects the color reagent.

The method finally adopted consisted of adding into colorimeter tubes an aliquot portion (one to five ml) of the samples, water until the volume was five ml, three ml of the mixed reagent, one ml of thiazole yellow solution, and two ml of 10 N NaOH. These were mixed well, set aside for twenty minutes for color development, and read at 540 millimicrons in the Evelyn colorimeter. The magnesium in the samples was calculated from the standard curve.

The Karo syrup samples were analyzed for moisture, ash, and the minerals, but not for nitrogen.

All analyses were carried out in duplicate and all values reprinted represent averages.

RESULTS AND DISCUSSION

The average values of the blood plasma values of the sheep on a normal and on a high protein, high potassium diet are shown in Table V.

Table V. Plasma Minerals of Sheep on a Normal Diet and on a Diet High in Protein and Potassium Expressed in Milligrams Percent.

Date Bled[1]		Feb. 4	Feb. 11	Feb. 16	Feb. 21	Mar. 18	Apr. 2	Apr. 18
Ration	Blood Constituent							
I	Mg	1.98	1.90	1.80	1.89	1.60	2.70	2.59
II	Mg	1.87	1.62	1.48	1.70	1.29	2.34	2.12
I	Ca	7.8	8.7	7.8	8.4	8.8	9.0	9.2
II	Ca	7.9	8.2	7.5	8.2	8.6	8.8	8.8
I	P	6.31	6.66	8.08	7.14	6.18	6.07	6.02
II	P	6.79	7.34	8.21	7.45	7.08	7.00	6.91
I	Na	356	357	364	351	378	355	374
II	Na	362	356	346	348	365	371	369
I	K	19.1	20.4	19.9	20.6	18.5	17.8	17.5
II	K	19.6	19.8	19.3	19.5	18.4	17.0	17.8

[1]Note: Experiment 1, February 6-11; Experiment 2, Trial I, March 13-23; Trial II, April 13-23.

The plasma magnesium values for the sheep on the high protein, high potassium ration (II) were consistently lower than those on the normal ration (I). During Experiment 1 there was a decrease in the plasma magnesium for the sheep on both rations but the greater decrease was observed in the animals on the high protein, high potassium diet. A differential between the two rations was also observed throughout Experiment 2. There is no adequate explanation of the rather substantial increase in blood magnesium observed between Trials I and II. It was at this point that the composition of the two rations was changed slightly, but it is not believed that this would cause so large a change in the plasma magnesium. The analysis was conducted the same throughout all blood samples. Known concentrations of magnesium were included in each group of analyses made.

There was a slight increase in the plasma calcium of the animals on each ration in all experiments.

The plasma inorganic phosphorus values increased in Experiment 1 and decreased in Experiment 2, with the animals on the high protein, high potassium ration having the higher values in all cases.

The sodium values in the blood plasma were higher than normal for sheep in all animals on both rations. The normal value for plasma sodium is 330 mg%. There was no detectable pattern of difference between the two rations.

The plasma potassium values were within the normal range of values. Here also no pattern of difference appeared.

The summary of the balance study data is given in Table VI.

As the animals in Experiment 1 had a large amount of orts the balance study for them will be difficult to interpret. There was an increase in the negative balance of nitrogen of the sheep on the high protein, high potassium ration as compared to those on the normal diet. The urinary nitrogen increased for the animals on the high protein, high potassium diet; the fecal nitrogen remained about the same, with a slight decrease for the sheep on the high protein, high potassium ration.

The calcium balance had a greater negative value for the animals on the high protein, high potassium diet, but they also had less intake, less fecal and urinary excreta than did the sheep on the normal ration.

Table VI. The Balance Data of Sheep on a Normal Ration and on a Ration High in Protein and Potassium. Spring, 1955.

	Experiment 1		Experiment 2			
			Trial I		Trial II	
	February 6-11		March 13-23		April 13-23	
	Ration I	Ration II	Ration I	Ration II	Ration I	Ration II
	gm	gm	gm	gm	gm	gm
Total N intake	46.4	74.2	79.7	227.8	92.2	286.8
Total fecal N	12.6	11.9	20.0	18.9	25.3	23.1
Total urinary N	40.0	73.1	66.9	226.4	69.2	262.1
N balance	-6.2	-10.9	-7.2	-17.9	-2.3	+1.6
Total Ca intake	15.1	11.8	26.9	27.2	29.0	30.2
Total fecal Ca	15.7	14.4	29.6	27.1	30.5	29.5
Total urinary Ca	1.0	.5	1.7	1.4	1.0	.5
Ca balance	-1.5	-3.5	-4.3	-1.2	-2.4	+.2
Total Mg intake	4.15	2.93	9.60	9.75	8.90	9.90
Total fecal Mg	2.59	2.43	4.41	6.63	5.24	7.80
Total urinary Mg	2.24	1.60	4.65	3.36	4.87	3.57
Mg balance	-.68	-1.10	+.54	-.24	-1.22	-1.47
Total P intake	10.8	5.4	18.2	16.9	22.2	25.6
Total fecal P	7.6	5.8	16.3	13.2	17.0	13.3
Total urinary P	.4	.4	3.0	4.3	4.6	7.0
P balance	+2.8	-.8	-1.1	-.6	+.6	+5.2
Total Na intake	1.01	1.34	2.44	3.42	2.04	3.43
Total fecal Na	.30	.34	.46	.25	.36	.19
Total urinary Na	1.87	4.38	3.05	4.21	2.68	4.07
Na balance	-1.16	-3.37	-1.06	-1.05	-1.01	-.84
Total K intake	33.4	76.8	52.3	188.0	65.9	255.9
Total fecal K	2.5	1.7	4.3	2.8	5.7	2.4
Total urinary K	28.3	48.3	48.5	178.1	54.1	240.9
K balance	+2.6	+26.8	- .5	+7.1	+6.1	+12.6

There was a greater negative magnesium balance for the animals on the high protein, high potassium ration than for those on the normal diet. The urinary output of the sheep on the former diet decreased.

The animals on the normal ration had a positive phosphorus balance, whereas the sheep on the high protein, high potassium ration had a negative phosphorus balance. The urinary output of both groups was the same, but since the intakes were different the fecal output was different, being lower for the sheep on the high protein, high potassium ration.

The sodium balance showed a greater negative value for the lambs on the high protein, high potassium diet, with their urinary output far greater.

The potassium balance was positive for the rams on both rations, but the sheep on the high protein, high potassium ration had a greater positive balance with less fecal and more urinary output.

In Experiment 2, the animals in Trial I showed a negative nitrogen balance, whereas the sheep on the high protein, high potassium ration in Trial II had a positive nitrogen balance. In Trial I, however, the lambs on this ration had a negative balance greater than the animals on the normal ration. The same decrease in fecal and increase in urinary output was noticed here as in Experiment 1.

The animals in Trial I had a negative calcium balance, with the sheep on the high protein, high potassium diet having the least value, whereas in Trial II the lambs on this ration were in a slight positive balance.

The lambs on the normal ration of Trial I had a positive magnesium balance, whereas in Trial II they had a negative magnesium balance. The animals on the high protein, high potassium ration in Experiment 2 had negative magnesium balances, with the rams in Trial I having the least value. From the data presented in the table, it can be seen that the animals on the high protein, high potassium diet excreted more magnesium in the feces and less in the urine than the lambs on the normal ration. This could indicate some interference of the metabolism of magnesium in those sheep on the high protein, high potassium ration and tends to support the claims that magnesium is not absorbed in animals grazing wheat pasturage.

The sheep in Trial I were in negative phosphorus balance; in Trial II they exhibited a positive phosphorus balance. There was a decrease in the fecal phosphorus and an increase in the urinary phosphorus of the lambs on the high protein, high potassium ration.

Negative sodium balance occurred in the animals on both rations and in both trials of Experiment 2. There was a decrease (almost one-half) in the fecal sodium and an increase in the urinary sodium in the sheep on the high protein, high potassium ration compared to those on the normal ration.

There was a slight negative potassium balance of the lambs on the normal ration of Trial I. The rams on the high protein, high potassium ration in both trials had less fecal potassium (about one-half) than the sheep on the normal ration in both trials. The urinary potassium was greatly increased in the sheep on the high protein, high potassium ration due to the excessive amount ingested.

Digestion coefficients were calculated for dry matter, organic matter, and protein. The average values are shown in Table VII.

In Experiment 1, there was a decrease in the digestion coefficients of dry matter and organic matter of the sheep on the high protein, high potassium ration in comparison with those on the normal ration, whereas the reverse was true for protein.

Table VII. Digestion Coefficients of Sheep During the Spring, 1955 Experiments

	Experiment 1		Experiment 2			
			Trial I		Trial II	
	February 6-11		March 13-23		April 13-23	
	Ration I	Ration II	Ration I	Ration II	Ration I	Ration II
Dry matter	76.49	66.13	80.56	83.00	79.87	82.88
Organic matter	78.41	67.59	82.77	83.99	82.00	83.74
Protein	73.02	81.85	74.48	91.49	72.55	91.94

In Experiment 2, there was little difference in the digestibility of the dry matter and the organic matter between the two rations; the digestibility of the protein fraction again was higher in the high protein, high potassium ration, 74.5 and 72.6 percent as compared with 91.5 and 91.9 for Rations I and II, respectively. This increase in protein digestibility of the high protein, high potassium ration is probably due to the fact that such a large portion of the total protein was furnished by the easily-soluble, purified, soybean protein.

The marked increase in the digestibility of the dry matter of Experiment 2 as compared with Experiment 1 is doubtless due to the fact that the feed intake, particularly of the readily-digestible concentrate portion, was so greatly reduced in the first experiment. The addition, moreover, of corn syrup, which should be almost completely absorbed, would increase the digestion coefficient of the dry matter in Experiment 2.

As there seems to be an effect on the absorption of magnesium by sheep on a high protein, high potassium ration, further work should be undertaken. A study of the effect of the pH of the intestine on the absorption of magnesium would be appropriate. It may well be that the animals should be kept longer on this type of ration to see what effect this treatment would have on them.

SUMMARY

A study was made of the effect of high protein and high potassium intake by sheep on the digestibility of the ration and the blood composition and body balance of certain minerals.

The blood composition of the sheep receiving the diet high in protein and in potassium differed from the animals receiving the diet containing normal levels of these constituents in exhibiting a decreased magnesium level and a slightly elevated phosphorus level. With respect to the usually accepted normal value for these blood constitutents, the plasma sodium of the animals in these experiments was high.

The balance studies showed that fecal nitrogen, calcium, phosphorus, sodium, and potassium were decreased in the animals on the high protein, high potassium diet with fecal sodium and potassium decreased about one-half. The phosphorus excretion via the feces was decreased by about one-fifth and the nitrogen and calcium excretion in the feces were just slightly decreased. The fecal magnesium, although slightly decreased in Experiment 1, was increased in Experiment 2 for the lambs on the high protein, high potassium ration, showing there might be an effect of this diet on magnesium absorption. The urinary output was greatly increased for nitrogen and potassium from the animals on the high protein, high potassium ration due to the excessive amount in the ration. Urinary calcium and magnesium were decreased on this ration, whereas urinary sodium and phosphorus were increased.

The coefficients of digestibility for dry matter and organic matter were slightly increased in Experiment 2 in the sheep on the high protein,

high potassium ration as compared to the rams on the normal diet, whereas the digestibility coefficient of protein of the lambs on the high protein, high potassium ration in Experiment 2 was increased 17 to 19 percent as compared to that of the animals on the normal ration.

Although the sheep on the high protein, high potassium ration did not exhibit any of the classical symptoms of grass tetany, it was demonstrated that this type of diet affects the metabolism of magnesium by decreasing its absorption through the intestines. This was reflected in a lowered blood magnesium level.

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APPENDIX TABLES

TABLE I

Blood Plasma Magnesium Levels of Cows Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Cow No. 1[1]	mg%	2.32	2.44	1.88	2.18	1.94	1.60	2.68
Cow No. 2	mg%	2.52	2.60	2.32	1.74	2.16	2.10	2.26
Average	mg%	2.42	2.52	2.10	1.96	2.05	1.85	2.47

TABLE II

Blood Plasma Magnesium Levels of Cows Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Cow No. 3	mg%	2.94	2.50	2.20	1.92	1.20	1.44	1.36
Cow No. 4	mg%	2.48	2.38	2.50	2.30	2.28	1.40	1.56
Average	mg%	2.71	2.44	2.35	2.11	1.74	1.42	1.46

TABLE III

Blood Plasma Magnesium Levels of Cows Grazing Fertilized "Short" Oats, Goodwell, Oklahoma, Spring 1954, Trial II

Day Bled		Before	1	2	3	4	5	6
Cow No. 4	mg%	——	2.60	2.48	2.50	2.38	2.74	3.00
Cow No. 2	mg%	2.60	2.94	2.64	2.44	2.16	2.46	2.66
Cow No. 1	mg%	2.60	3.06	2.58	1.90	2.38	2.86	2.78
Cow No. 3	mg%	2.50	2.48	2.38	2.40	1.96	2.10	2.84
Cow No. 5	mg%	2.74	3.10	3.24	1.84	2.64	2.86	2.54
Average	mg%	2.61	2.84	2.66	2.12	2.30	2.60	2.76

TABLE IV

Blood Plasma Magnesium Levels of Sheep Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trail I

Day Bled		1	2	3	5	7	10	15
Sheep No. 272	mg%	1.98	2.78	2.60	2.38	2.70	2.20	1.74
Sheep No. 278	mg%	2.24	2.28	2.78	2.38	2.50	2.38	2.28
Average	mg%	2.11	2.53	2.69	2.38	2.60	2.29	2.01

[1] Cow No. 1, Ethyl; Cow No. 2, Helen; Cow No. 3, Louise; Cow No. 4, Guernsey; Cow No. 5, Blue.

TABLE V

Blood Plasma Magnesium Levels of Sheep Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring, 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Sheep No. 559	mg%	2.24	2.30	2.30	2.60	2.64	2.40	2.50
Sheep No. 597	mg%	2.76	2.20	2.54	2.20	2.24	2.26	2.04
Average	mg%	2.50	2.25	2.42	2.40	2.44	2.33	2.27

TABLE VI

Blood Plasma Calcium Levels of Cows Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring, 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Cow No. 1	mg%	8.9	9.6	9.5	9.6	10.6	9.8	8.0
Cow No. 2	mg%	9.8	10.5	9.6	9.0	10.3	9.8	11.1
Average	mg%	9.4	10.0	9.6	9.3	10.4	9.8	9.6

TABLE VII

Blood Plasma Calcium Levels of Cows Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring, 1954, Trail I

Day Bled		1	2	3	5	7	10	15
Cow No. 3	mg%	10.4	10.1	11.1	10.1	9.1	10.4	10.6
Cow No. 4	mg%	11.6	10.6	9.7	11.2	10.4	9.7	11.1
Average	mg%	11.0	10.4	10.4	10.6	9.8	10.0	10.8

TABLE VIII

Blood Plasma Calcium Levels of Cows Grazing Fertilized "Short" Oats, Goodwell, Oklahoma, Spring, 1954, Trial II

Day Bled		Before	1	2	3	4	5	6
Cow No. 4	mg%	--	9.1	9.6	10.3	10.0	9.4	9.2
Cow No. 2	mg%	8.9	8.0	10.1	10.3	8.8	9.2	9.1
Cow No. 1	mg%	8.4	9.0	9.0	9.4	9.8	9.2	8.4
Cow No. 3	mg%	10.5	8.3	10.7	10.3	9.2	9.1	9.3
Cow No. 5	mg%	9.7	9.4	9.7	9.2	8.3	9.2	9.5
Average	mg%	9.4	8.8	9.8	9.9	9.2	9.2	9.1

TABLE IX

Blood Plasma Calcium Levels of Sheep Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Sheep No. 272	mg%	9.1	9.1	10.2	11.2	9.7	10.5	10.6
Sheep No. 278	mg%	9.2	10.0	9.1	10.7	10.6	10.6	10.8
Average	mg%	9.2	9.6	9.6	11.0	10.2	10.6	10.7

TABLE X

Blood Plasma Calcium Levels of Sheep Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Sheep No. 559	mg%	9.4	10.0	10.2	11.2	9.5	9.6	10.6
Sheep No. 597	mg%	10.9	9.9	11.2	10.3	11.0	11.3	10.9
Average	mg%	10.2	10.0	10.7	10.8	10.2	10.4	10.8

TABLE XI

Blood Plasma Phosphorus[1] Levels of Cows Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trail I.

Day Bled		1	2	3	5	7	10	15
Cow No. 1	mg%	4.48	4.08	5.28	5.40	5.24	5.08	3.72
Cow No. 2	mg%	3.84	4.36	6.16	5.52	5.76	5.40	4.80
Average	mg%	4.16	4.22	5.72	5.46	5.50	5.24	4.26

TABLE XII

Blood Plasma Phosphorus Levels of Cows Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Cow No. 3	mg%	4.36	4.88	5.60	5.08	4.96	4.96	4.92
Cow No. 4	mg%	4.08	4.60	4.96	4.64	4.52	4.32	3.84
Average	mg%	4.22	4.74	5.28	4.86	4.74	4.64	4.38

[1]All blood plasma phosphorus values given in these tables are inorganic phosphorus.

TABLE XIII

Blood Plasma Phosphorus Levels of Cows Grazing Fertilized "Short" Oats, Goodwell, Oklahoma, Spring 1954, Trial II

Day Bled		Before	1	2	3	4	5	6
Cow No. 4	mg%	--	5.48	6.68	6.32	5.60	4.40	4.04
Cow No. 2	mg%	4.88	4.44	9.32	9.60	7.48	7.72	6.08
Cow No. 1	mg%	6.68	6.84	9.56	8.32	7.84	4.76	5.20
Cow No. 3	mg%	7.32	7.28	8.12	7.80	6.16	5.80	5.36
Cow No. 5	mg%	7.84	7.12	8.96	8.32	5.80	5.36	3.36
Average	mg%	6.68	6.23	8.53	8.07	6.58	5.61	4.81

TABLE XIV

Blood Plasma Phosphorus Levels of Sheep Grazing Unfertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Sheep No. 272	mg%	3.68	4.24	3.68	4.04	5.24	4.08	4.20
Sheep No. 278	mg%	4.00	4.32	4.12	4.04	5.00	4.12	3.48
Average	mg%	3.84	4.28	3.90	4.04	5.12	4.10	3.84

TABLE XV

Blood Plasma Phosphorus Levels of Sheep Grazing Fertilized "Short" Wheat, Goodwell, Oklahoma, Spring 1954, Trial I

Day Bled		1	2	3	5	7	10	15
Sheep No. 559	mg%	3.48	3.84	3.56	3.56	4.76	3.88	4.36
Sheep No. 597	mg%	3.60	3.80	3.60	4.36	3.84	4.44	2.52
Average	mg%	3.54	3.82	3.58	3.96	4.30	4.16	3.44

TABLE XVI

Blood Plasma Magnesium Levels of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet

Date Bled		4 Feb.[1]	11 Feb.	16 Feb.	21 Feb.	18 Mr.	2 Apr.	18 Apr.
Ration I								
Sheep No. 3	mg%	1.54	1.46	1.96	1.96	1.26	2.80	2.78
8	mg%	2.04	1.96	1.60	1.96	1.78	2.74	2.52
9	mg%	2.08	1.90	1.82	1.82	1.46	2.58	2.62
12	mg%	2.08	2.02	1.96	1.80	1.74	2.80	2.60
13	mg%	1.94	2.06	1.82	1.96	1.78	2.74	2.74
15	mg%	2.18	2.00	1.66	1.84	1.60	2.52	2.26
Average	mg%	1.98	1.90	1.80	1.89	1.60	2.70	2.59
Ration II								
Sheep No. 4	mg%	2.14	1.48	1.56	1.70	1.14	2.40	2.14
5	mg%	1.84	1.40	1.50	1.72	1.08	2.46	2.28
6	mg%	1.48	1.62	1.54	1.68	1.34	2.52	2.06
7	mg%	1.56	1.72	1.56	1.86	1.50	2.24	2.00
11	mg%	2.12	1.44	.98	—	—	—	—
10	mg%	—	—	1.64[2]	1.56	1.08	2.20	2.22
14	mg%	2.10	2.04	1.56	1.68	1.60	2.24	2.04
Average	mg%	1.87	1.62	1.48	1.70	1.29	2.34	2.12

TABLE XVII

Blood Plasma Phosphorus Levels of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet

Date Bled		4 Feb.	11 Feb.	16 Feb.	21 Feb.	18 Mar.	2 Apr.	18 Apr.
Ration I								
Sheep No. 3	mg%	7.55	6.85	9.40	9.40	6.40	7.55	7.30
8	mg%	6.25	6.05	6.80	5.10	5.80	4.65	6.70
9	mg%	5.60	6.60	7.75	6.85	4.90	5.40	5.35
12	mg%	6.75	7.65	8.50	7.55	7.15	6.25	5.60
13	mg%	5.20	7.40	7.20	7.00	6.70	7.10	6.65
15	mg%	6.50	5.40	8.80	6.95	6.15	5.45	4.55
Average	mg%	6.31	6.66	8.08	7.14	6.18	6.07	6.02
Ration II								
Sheep No. 4	mg%	6.75	7.90	8.45	7.55	7.15	6.50	7.50
5	mg%	6.55	6.25	8.00	6.40	7.15	8.10	7.75
6	mg%	7.55	6.95	7.45	8.05	6.90	7.25	6.60
7	mg%	6.60	8.45	8.90	7.65	7.35	7.70	6.65
11	mg%	6.65	7.25	10.25	—	—	—	—
10	mg%	—	—	5.05	7.40	6.35	5.60	5.85
14	mg%	6.65	7.25	9.35	7.65	7.60	6.85	7.10
Average	mg%	6.79	7.34	8.21	7.45	7.08	7.00	6.91

[1] Experiment 1 was conducted on 6-11 Feb., 1955, Experiment 2, Trial I was conducted on 13-23 March 1955, Experiment 2, Trial II was conducted on 13-23 April 1955.

[2] Sheep No. 10 bled on 18 Feb. 1955 when listed in this column. It is included in average.

TABLE XVIII

Blood Plasma Calcium Levels of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet

Date Bled		4 Feb.	11 Feb.	16 Feb.	21 Feb.	18 Mar.	2 Apr.	18 Apr.
Ration I								
Sheep No. 3	mg%	7.0	8.9	7.7	8.0	8.4	9.2	8.7
8	mg%	8.2	9.0	7.6	9.0	9.1	9.0	9.7
9	mg%	7.8	8.5	8.0	8.4	8.7	8.5	9.6
12	mg%	8.3	8.7	8.3	8.8	8.7	9.0	9.0
13	mg%	8.5	7.9	7.1	8.1	9.0	8.5	9.1
15	mg%	7.0	9.1	8.3	7.9	8.9	9.6	9.4
Average	mg%	7.8	8.7	7.8	8.4	8.8	9.0	9.2
Ration II								
Sheep No. 4	mg%	8.2	7.9	7.5	7.8	7.7	9.2	8.9
5	mg%	7.7	7.4	7.8	8.2	9.8	8.7	8.9
6	mg%	7.9	7.8	7.2	8.7	9.0	8.7	8.9
7	mg%	8.4	8.6	8.2	8.9	8.2	8.8	8.7
11	mg%	8.0	8.7	6.5	—	—	—	—
10	mg%	—	—	7.5	8.0	8.6	9.1	9.1
14	mg%	7.4	8.8	7.7	7.9	8.4	8.2	8.0
Average	mg%	7.9	8.2	7.5	8.2	8.6	8.8	8.8

TABLE XIX

Blood Plasma Sodium Levels of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet

Date Bled		4 Feb.	11 Feb.	16 Feb.	21 Feb.	18 Mar.	2 Apr.	18 Apr.
Ration I								
Sheep No. 3	mg%	345	338	365	370	338	322	388
8	mg%	370	350	365	335	375	388	365
9	mg%	365	360	370	350	382	365	375
12	mg%	360	368	358	355	388	358	365
13	mg%	345	360	355	348	395	322	375
15	mg%	350	365	370	350	388	375	375
Average	mg%	356	357	364	351	378	355	374
Ration II								
Sheep No. 4	mg%	360	345	365	360	350	365	375
5	mg%	355	350	360	350	358	365	365
6	mg%	370	355	370	340	365	375	375
7	mg%	370	358	370	332	365	400	365
11	mg%	370	365	370	—	—	—	—
10	mg%	—	—	335	350	375	358	358
14	mg%	350	365	355	355	375	365	375
Average	mg%	362	356	346	348	365	371	369

TABLE XX

Blood Plasma Potassium Levels of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet

Date Bled		4 Feb.	11 Feb.	16 Feb.	21 Feb.	18 Mar.	2 Apr.	18 Apr.
Ration I								
Sheep No. 3	mg%	19.5	21.5	21.2	21.5	17.5	16.5	17.2
8	mg%	18.0	22.8	19.5	21.8	19.5	18.2	19.0
9	mg%	17.8	18.8	18.0	18.8	18.5	18.2	17.0
12	mg%	19.5	18.8	19.5	20.8	18.8	19.2	17.2
13	mg%	19.8	21.2	19.5	19.8	18.2	17.2	17.2
15	mg%	20.0	19.5	21.5	21.0	18.5	17.2	18.2
Average	mg%	19.1	20.4	19.9	20.6	18.5	17.8	17.5
Ration II								
Sheep No. 4	mg%	19.0	19.5	20.5	19.2	18.5	17.0	19.0
5	mg%	17.8	18.8	18.0	18.5	17.5	17.0	17.0
6	mg%	21.8	18.5	18.5	19.0	18.5	16.5	17.2
7	mg%	18.5	21.5	20.0	20.0	17.8	17.8	17.0
11	mg%	19.5	19.0	18.0	——	——	——	——
10	mg%	——	——	19.5	17.8	17.2	17.0	17.2
14	mg%	21.2	21.5	20.8	22.5	20.8	17.0	19.2
Average	mg%	19.6	19.8	19.3	19.5	18.4	17.0	17.8

TABLE XXI

Nitrogen Intake and Excretion and Nitrogen Balance of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed N	Total Orts	Total Orts N	Total N Intake	Total Feces	Total Fecal N	Total Urine	Total Urinary N	Nitrogen Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	50.4	333	6.3	44.1	370	9.5	16.0	38.4	-3.8
Ration I	8	2427	50.4	262	4.5	45.9	463	11.3	16.0	38.4	-3.8
Ration I	9	2427	50.4	533	3.6	46.8	503	13.3	16.0	38.4	-4.9
Ration I	12	2427	50.4	208	2.8	47.6	507	13.1	16.0	40.0	-5.5
Ration I	13	2427	50.4	226	4.0	46.4	649	15.4	16.0	44.8	-13.8
Ration I	15	2427	50.4	156	2.9	47.5	525	13.0	16.0	40.0	-5.5
Average						46.4		12.6		40.0	-6.2
Ration II	4	2672	167.7	974	80.1	87.6	488	11.6	16.0	80.0	-4.0
Ration II	5	2672	167.7	1046	87.0	80.7	540	12.7	16.0	80.0	-12.0
Ration II	6	2672	167.7	1034	83.5	84.2	431	11.5	16.1	62.8	+9.9
Ration II	7	2672	167.7	1628	128.6	39.1	376	8.8	16.0	52.8	-22.5
Ration II	11	2672	167.7	1793	132.2	35.5	446	10.8	16.0	59.2	-34.5
Ration II	14	2672	167.7	624	49.7	118.0	578	16.2	16.0	104.0	-2.2
Average						74.2		11.9		73.1	-10.9
Experiment 2 Trial I											
Ration I	3	3990	80.5	--	--	80.5	704	16.9	51.0	71.4	-7.8
Ration I	8	3990	80.5	--	--	80.5	881	24.1	50.0	75.0	-18.6
Ration I	9	3990	80.5	215	4.7	75.8	811	24.2	50.0	55.0	-3.4
Ration I	12	3990	80.5	--	--	80.5	690	16.0	50.0	75.0	-10.5
Ration I	13	3990	80.5	--	--	80.5	813	21.8	50.0	60.0	-1.3
Ration I	15	3990	80.5	--	--	80.5	708	17.2	50.0	65.0	-1.7
Average						79.7		20.0		66.9	-7.2

Ration II	4	4333	227.8	--	--	227.8	765	20.0	50.0	220.0	-14.2
Ration II	5	4333	227.8	--	--	227.8	770	19.8	50.5	222.2	-14.2
Ration II	6	4333	227.8	--	--	227.8	705	17.5	50.0	230.0	-19.7
Ration II	7	4333	227.8	--	--	227.8	734	18.9	51.0	234.6	-25.7
Ration II	10[1]	4333	227.8	--	--	227.8	724	21.8	50.0	190.0	+16.0
Ration II	14	4333	227.8	--	--	227.8	721	18.4	50.0	225.0	-15.6
Average						227.8		18.9		226.4	-17.9
Experiment 2 Trial II											
Ration I	3	4639	92.4	--	--	92.4	929	24.7	54.4	65.3	+2.4
Ration I	8	4639	92.4	--	--	92.4	918	22.6	50.0	70.0	- .2
Ration I	9	4639	92.4	49	1.2	91.2	1089	34.0	50.0	55.0	+2.2
Ration I	12	4639	92.4	--	--	92.4	805	20.1	50.0	75.0	-2.7
Ration I	13	4639	92.4	--	--	92.4	956	26.7	50.0	70.0	-4.3
Ration I	15	4639	92.4	--	--	92.4	895	23.7	50.0	80.0	-11.3
Average						92.2		25.3		69.2	-2.3
Ration II	4	5142	287.8	60	5.0	282.8	870	22.9	50.5	257.6	+2.3
Ration II	5	5142	287.8	--	--	287.8	932	24.9	50.5	262.6	+ .3
Ration II	6	5142	287.8	--	--	287.8	852	21.6	51.0	265.2	+1.0
Ration II	7	5142	287.8	--	--	287.8	871	23.4	50.0	260.0	+4.4
Ration II	10[1]	5142	287.8	--	--	287.8	873	23.3	50.0	140.0	+124.5
Ration II	14	5142	287.8	--	--	287.8	872	22.7	50.0	265.0	+ .1
Average						286.8		23.1		262.1	+1.6

[1] No. 10 not included in average values.

TABLE XXII

Calcium Intake and Excretion and Calcium Balance of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed Ca	Total Orts	Total Orts Ca	Total Ca Intake	Total Feces	Total Fecal Ca	Total Urine	Total Urinary Ca	Calcium Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	16.1	333	1.4	14.7	370	12.2	16.0	.7	+1.8
Ration I	8	2427	16.1	262	.8	15.3	463	15.0	16.0	1.2	- .9
Ration I	9	2427	16.1	533	1.7	14.4	503	14.7	16.0	.7	-1.0
Ration I	12	2427	16.1	208	.9	15.2	507	16.1	16.0	.9	-1.8
Ration I	13	2427	16.1	226	.7	15.4	649	20.5	16.0	1.4	-6.5
Ration I	15	2427	16.1	156	.5	15.6	525	15.6	16.0	.8	- .8
Average						15.1		15.7		1.0	-1.5
Ration II	4	2672	16.2	974	3.1	13.1	488	15.4	16.0	.6	-2.9
Ration II	5	2672	16.2	1046	3.2	13.0	540	14.6	16.0	.7	-2.3
Ration II	6	2672	16.2	1034	2.9	13.3	431	13.5	16.1	.6	- .8
Ration II	7	2672	16.2	1628	6.1	10.1	376	12.3	16.0	1.2	-3.4
Ration II	11	2672	16.2	1793	8.0	8.1	446	14.3	16.0	2.0	-8.2
Ration II	14	2672	16.2	624	2.5	13.7	578	16.5	16.0	.5	-3.3
Average						11.8		14.4		.9	-3.5
Experiment 2 Trial I											
Ration I	3	3990	27.2	--	--	27.2	704	29.4	51.0	1.2	-3.4
Ration I	8	3990	27.2	--	--	27.2	881	34.2	50.0	1.8	-8.8
Ration I	9	3990	27.2	215	1.6	25.6	811	29.2	50.0	1.9	-5.5
Ration I	12	3990	27.2	--	--	27.2	690	27.9	50.0	1.6	-2.3
Ration I	13	3990	27.2	--	--	27.2	813	31.5	50.0	1.8	-6.1
Ration I	15	3990	27.2	--	--	27.2	708	25.3	50.0	1.7	+ .2
Average						26.9		29.6		1.7	-4.3

Ration II	4	4333	27.2	--	--	27.2	765	28.0	50.0	1.2	-2.0
Ration II	5	4333	27.2	--	--	27.2	770	27.9	50.5	1.3	-2.0
Ration II	6	4333	27.2	--	--	27.2	705	25.9	50.0	1.5	- .2
Ration II	7	4333	27.2	--	--	27.2	734	28.5	51.0	1.4	-2.7
Ration II	10[1]	4333	27.2	--	--	27.2	724	27.4	50.0	1.5	-1.7
Ration II	14	4333	27.2	--	--	27.2	721	25.0	50.0	1.4	+ .8
Average						27.2		27.1		1.4	-1.2
Experiment 2 Trial II											
Ration I	3	4639	29.1	--	--	29.1	929	30.7	54.4	.3	-1.9
Ration I	8	4639	29.1	--	--	29.1	918	31.8	50.0	1.1	-3.8
Ration I	9	4639	29.1	49	.3	28.8	1089	32.7	50.0	1.3	-5.2
Ration I	12	4639	29.1	--	--	29.1	805	29.4	50.0	1.1	-1.4
Ration I	13	4639	29.1	--	--	29.1	956	30.7	50.0	1.2	-2.8
Ration I	15	4639	29.1	--	--	29.1	895	27.5	50.0	1.2	+ .4
Average						29.0		30.5		1.0	-2.4
Ration II	4	5142	30.3	60	.2	30.1	870	27.9	50.5	.5	+1.7
Ration II	5	5142	30.3	--	--	30.3	932	31.0	50.5	.3	-1.0
Ration II	6	5142	30.3	--	--	30.3	852	27.9	51.0	.8	+1.6
Ration II	7	5142	30.3	--	--	30.3	871	30.6	50.0	.6	- .9
Ration II	10[1]	5142	30.3	--	--	30.3	873	29.9	50.0	.9	- .5
Ration II	14	5142	30.3	--	--	30.3	872	30.0	50.0	.5	- .2
Average						30.2		29.5		.5	+ .2

[1]Number 10 not included in average values.

TABLE XXIII

Magnesium Intake and Excretion and Magnesium Balance of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed Mg	Total Orts	Total Orts Mg	Total Mg Intake	Total Feces	Total Fecal Mg	Total Urine	Total Urinary Mg	Magnesium Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	4.56	333	.55	4.01	370	1.97	16.0	2.29	- .25
Ration I	8	2427	4.56	262	.35	4.21	463	2.38	16.0	2.22	- .39
Ration I	9	2427	4.56	533	.73	3.83	503	2.58	16.0	2.03	- .78
Ration I	12	2427	4.56	208	.31	4.25	507	2.84	16.0	2.34	- .93
Ration I	13	2427	4.56	226	.28	4.28	649	2.99	16.0	2.34	-1.05
Ration I	15	2427	4.56	156	.22	4.34	525	2.77	16.0	2.24	- .67
Average						4.15		2.59		2.24	- .68
Ration II	4	2672	4.70	974	1.38	3.32	488	2.58	16.0	1.73	- .99
Ration II	5	2672	4.70	1046	1.57	3.13	540	2.62	16.0	1.62	-1.11
Ration II	6	2672	4.70	1034	1.46	3.24	431	2.65	16.1	1.40	- .81
Ration II	7	2672	4.70	1628	2.56	2.14	376	1.99	16.0	1.62	-1.47
Ration II	11	2672	4.70	1793	2.74	1.96	446	1.92	16.0	1.68	-1.64
Ration II	14	2672	4.70	624	.91	3.79	578	2.83	16.0	1.52	- .56
Average						2.93		2.43		1.60	-1.10
Experiment 2 Trial I											
Ration I	3	3990	9.66	—	—	9.66	704	4.23	51.0	5.71	- .28
Ration I	8	3990	9.66	—	—	9.66	881	5.02	50.0	4.50	+ .14
Ration I	9	3990	9.66	215	.39	9.27	811	4.00	50.0	4.50	+ .77
Ration I	12	3990	9.66	—	—	9.66	690	3.96	50.0	4.80	+ .90
Ration I	13	3990	9.66	—	—	9.66	813	4.80	50.0	4.20	+ .66
Ration I	15	3990	9.66	—	—	9.66	708	4.43	50.0	4.20	+1.03
Average						9.60		4.41		4.65	+ .54

Ration II	4	4333	9.75	--	--	9.75	765	6.97	50.0	3.35	- .57
Ration II	5	4333	9.75	--	--	9.75	770	7.08	50.5	2.68	- .01
Ration II	6	4333	9.75	--	--	9.75	705	6.06	50.0	3.90	- .21
Ration II	7	4333	9.75	--	--	9.75	734	6.81	51.0	3.42	- .48
Ration II	10[1]	4333	9.75	--	--	9.75	724	6.06	50.0	3.20	+ .49
Ration II	14	4333	9.75			9.75	721	6.24	50.0	3.45	+ .06
Average						9.75		6.63		3.36	- .24
Experiment 2 Trial 2											
Ration I	3	4639	8.91	--	--	8.91	929	4.76	54.4	5.60	-1.45
Ration I	8	4639	8.91	--	--	8.91	918	5.43	50.0	4.95	-1.47
Ration I	9	4639	8.91	49	.09	8.82	1089	5.94	50.0	4.70	-1.82
Ration I	12	4639	8.91	--	--	8.91	805	4.40	50.0	5.05	- .54
Ration I	13	4639	8.91	--	--	8.91	956	5.37	50.0	4.10	- .56
Ration I	15	4639	8.91	--	--	8.91	895	5.57	50.0	4.80	-1.46
Average						8.90		5.24		4.87	-1.22
Ration II	4	5142	9.92	60	.09	9.83	870	7.30	50.5	3.89	-1.36
Ration II	5	5142	9.92	--	--	9.92	932	8.39	50.5	2.27	- .74
Ration II	6	5142	9.92	--	--	9.92	852	7.36	51.0	4.39	-1.83
Ration II	7	5142	9.92	--	--	9.92	871	8.01	50.0	3.50	-1.59
Ration II	10[1]	5142	9.92	--	--	9.92	873	7.51	50.0	2.25	+ .16
Ration II	14	5142	9.92	--	--	9.92	872	7.93	50.0	3.80	-1.81
Average						9.90		7.80		3.57	-1.47

[1]Number 10 not included in average values.

TABLE XXIV

Phosphorus Intake and Excretion and Phosphorus Balance of Sheep on Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed P	Total Orts	Total Orts P	Total P Intake	Total Feces	Total Fecal P	Total Urine	Total Urinary P	Phosphorus Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	12.6	333	2.0	10.6	370	5.8	16.0	.4	+4.4
Ration I	8	2427	12.6	262	1.6	11.0	463	7.3	16.0	.3	+3.4
Ration I	9	2427	12.6	533	3.4	9.2	503	7.1	16.0	.3	+1.8
Ration I	12	2427	12.6	208	1.3	11.3	507	7.0	16.0	.4	+3.9
Ration I	13	2427	12.6	226	1.4	11.2	649	10.9	16.0	.4	- .1
Ration I	15	2427	12.6	156	1.1	11.5	525	7.8	16.0	.3	+3.4
Average						10.8		7.6		.4	+2.8
Ration II	4	2672	11.5	974	5.1	6.4	488	6.6	16.0	.4	- .6
Ration II	5	2672	11.5	1046	5.4	6.1	540	5.5	16.0	.3	+ .3
Ration II	6	2672	11.5	1034	5.4	6.1	431	4.7	16.1	.6	+ .8
Ration II	7	2672	11.5	1628	8.1	3.4	376	4.5	16.0	.2	-1.3
Ration II	11	2672	11.5	1793	9.0	2.5	446	5.9	16.0	.4	-3.8
Ration II	14	2672	11.5	624	3.4	8.1	578	7.7	16.0	.5	- .1
Average						5.4		5.8		.4	- .8
Experiment 2 Trial I											
Ration I	3	3990	18.4	--	--	18.4	704	10.5	51.0	9.5	-1.6
Ration I	8	3990	18.4	--	--	18.4	881	20.4	50.0	.8	-2.8
Ration I	9	3990	18.4	215	1.2	17.2	811	17 [illegible]	50.0	.7	-1.3
Ration I	12	3990	18.4	--	--	18.4	690	13.9	50.0	5.4	- .9
Ration I	13	3990	18.4	--	--	18.4	813	18.6	50.0	.8	-1.0
Ration I	15	3990	18.4	--	--	18.4	708	16.6	50.0	1.0	+ .8
Average						18.2		16.3		3.0	-1.1

Ration II	4	4333	16.9	--	--	16.9	765	14.6	50.0	3.2	- .9
Ration II	5	4333	16.9	--	--	16.9	770	16.5	50.5	.9	- .5
Ration II	6	4333	16.9	--	--	16.9	705	8.2	50.0	8.8	- .1
Ration II	7	4333	16.9	--	--	16.9	734	13.4	51.0	4.7	-1.2
Ration II	10[1]	4333	16.9	--	--	16.9	724	12.4	50.0	4.2	+ .3
Ration II	14	4333	16.9	--	--	16.9	721	13.3	50.0	3.9	- .3
Average						16.9		13.2		4.3	- .6
Experiment 2 Trial II											
Ration I	3	4639	22.3	--	--	22.3	929	10.8	54.4	11.3	+ .2
Ration I	8	4639	22.3	--	--	22.3	918	20.6	50.0	1.0	+ .7
Ration I	9	4639	22.3	49	.4	21.9	1089	21.4	50.0	1.0	- .5
Ration I	12	4639	22.3	--	--	22.3	805	9.6	50.0	11.2	+1.5
Ration I	13	4639	22.3	--	--	22.3	956	19.6	50.0	2.4	+ .3
Ration I	15	4639	22.3	--	--	22.3	895	19.8	50.0	1.0	+1.5
Average						22.2		17.0		4.6	+ .6
Ration II	4	5142	25.7	60	.5	25.2	870	13.3	50.5	6.3	+5.6
Ration II	5	5142	25.7	--	--	25.7	932	18.9	50.5	2.2	+4.6
Ration II	6	5142	25.7	--	--	25.7	852	7.4	51.0	12.0	+6.3
Ration II	7	5142	25.7	--	--	25.7	871	13.0	50.0	8.0	+4.7
Ration II	10[1]	5142	25.7	--	--	25.7	873	14.4	50.0	4.0	+7.3
Ration II	14	5142	25.7	--	--	25.7	872	13.7	50.0	6.7	+5.3
Average						25.6		13.3		7.0	+5.2

[1]Number 10 not included in average values.

TABLE XXV

Sodium Intake and Excretion and Sodium Balance of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed Na	Total Orts	Total Orts Na	Total Na Intake	Total Feces	Total Fecal Na	Total Urine	Total Urinary Na	Sodium Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	1.14	333	.17	.97	370	.22	16.0	1.44	- .69
Ration I	8	2427	1.14	262	.12	1.02	463	.26	16.0	1.92	-1.16
Ration I	9	2427	1.14	533	.20	.94	503	.25	16.0	2.24	-1.55
Ration I	12	2427	1.14	208	.10	1.04	507	.36	16.0	1.28	- .60
Ration I	13	2427	1.14	226	.12	1.02	649	.40	16.0	1.92	-1.30
Ration I	15	2427	1.14	156	.05	1.09	525	.32	16.0	2.40	-1.63
Average						1.01		.30		1.87	-1.16
Ration II	4	2672	2.38	974	.87	1.51	488	.17	16.0	5.28	-3.94
Ration II	5	2672	2.38	1046	.99	1.39	540	.76	16.0	6.40	-5.77
Ration II	6	2672	2.38	1034	.93	1.45	431	.28	16.1	3.38	-2.21
Ration II	7	2672	2.38	1628	1.37	1.01	376	.16	16.0	3.04	-2.19
Ration II	11	2672	2.38	1793	1.49	.89	446	.32	16.0	2.24	-1.67
Ration II	14	2672	2.38	624	.58	1.80	578	.34	16.0	5.92	-4.46
Average						1.34		.34		4.38	-3.37
Experiment 2 Trial I											
Ration I	3	3990	2.47	--	--	2.47	704	.18	51.0	3.21	- .92
Ration I	8	3990	2.47	--	--	2.47	881	.70	50.0	3.60	-1.83
Ration I	9	3990	2.47	215	.16	2.31	811	.29	50.0	2.75	- .73
Ration I	12	3990	2.47	--	--	2.47	690	1.05	50.0	2.85	-1.43
Ration I	13	3990	2.47	--	--	2.47	813	.21	50.0	2.50	- .24
Ration I	15	3990	2.47	--	--	2.47	708	.31	50.0	3.40	-1.24
Average						2.44		.46		3.05	-1.06

Ration II	4	4333	3.42	--	--	3.42	765	.17	50.0	4.90	-1.65
Ration II	5	4333	3.42	--	--	3.42	770	.31	50.5	3.84	- .73
Ration II	6	4333	3.42	--	--	3.42	705	.27	50.0	4.70	-1.55
Ration II	7	4333	3.42	--	--	3.42	734	.15	51.0	3.98	- .71
Ration II	10[1]	4333	3.42	--	--	3.42	724	.16	50.0	2.95	+ .31
Ration II	14	4333	3.42	--	--	3.42	721	.37	50.0	3.65	- .60
Average						3.42		.25		4.21	-1.05
Experiment 2 Trial II											
Ration I	3	4639	2.04	--	--	2.04	929	.14	54.4	3.21	-1.31
Ration I	8	4639	2.04	--	--	2.04	918	.33	50.0	2.35	- .64
Ration I	9	4639	2.04	49	.03	2.01	1089	.15	50.0	2.20	- .34
Ration I	12	4639	2.04	--	--	2.04	805	1.09	50.0	2.70	-1.75
Ration I	13	4639	2.04	--	--	2.04	956	.27	50.0	2.80	-1.03
Ration I	15	4639	2.04	--	--	2.04	895	.21	50.0	2.80	- .97
Average						2.04		.36		2.68	-1.01
Ration II	4	5142	3.44	60	.06	3.38	870	.12	50.5	4.09	- .83
Ration II	5	5142	3.44	--	--	3.44	932	.29	50.5	3.89	- .74
Ration II	6	5142	3.44	--	--	3.44	852	.27	51.0	4.39	-1.22
Ration II	7	5142	3.44	--	--	3.44	871	.13	50.0	4.10	- .79
Ration II	10[1]	5142	3.44	--	--	3.44	873	.13	50.0	3.30	+ .01
Ration II	14	5142	3.44	--	--	3.44	872	.15	50.0	3.90	- .61
Average						3.43		.19		4.07	- .84

[1]Number 10 not included in average values.

TABLE XXVI

Potassium Intake and Excretion and Potassium Balance of Sheep on a Normal Protein and Potassium Diet and on a High Protein and Potassium Diet.

Experiment 1	Sheep Number	Total Feed Fed	Total Feed K	Total Orts	Total Orts K	Total K Intake	Total Feces	Total Fecal K	Total Urine	Total Urinary K	Potassium Balance
		gm.	gm.	gm.	gm.	gm.	gm.	gm.	kg.	gm.	gm.
Ration I	3	2427	36.4	333	3.6	32.8	370	1.7	16.0	28.8	+2.3
Ration I	8	2427	36.4	262	2.6	33.8	463	2.1	16.0	28.8	+2.9
Ration I	9	2427	36.4	533	5.8	30.6	503	2.4	16.0	25.6	+2.6
Ration I	12	2427	36.4	208	2.4	34.0	507	2.3	16.0	28.8	+2.9
Ration I	13	2427	36.4	226	2.0	34.4	649	3.8	16.0	28.8	+1.8
Ration I	15	2427	36.4	156	1.8	34.6	525	2.6	16.0	28.8	+3.2
Average						33.4		2.5		28.3	+2.6
Ration II	4	2672	159.5	974	74.5	85.0	488	1.4	16.0	60.8	+22.8
Ration II	5	2672	159.5	1046	76.5	83.0	540	1.2	16.0	57.6	+24.2
Ration II	6	2672	159.5	1034	76.8	82.7	431	1.0	16.1	40.2	+41.5
Ration II	7	2672	159.5	1628	111.8	47.7	376	.7	16.0	27.2	+19.8
Ration II	11	2672	159.5	1793	114.9	44.6	446	2.1	16.0	24.0	+18.5
Ration II	14	2672	159.5	624	41.6	117.9	578	3.8	16.0	80.0	+34.1
Average						76.8		1.7		48.3	+26.8
Experiment 2 Trial I											
Ration I	3	3990	52.8	--	--	52.8	704	2.1	51.0	51.0	- .3
Ration I	8	3990	52.8	--	--	52.8	881	6.4	50.0	50.0	-3.6
Ration I	9	3990	52.8	215	2.9	49.9	811	4.6	50.0	45.0	+ .3
Ration I	12	3990	52.8	--	--	52.8	690	3.5	50.0	50.0	- .7
Ration I	13	3990	52.8	--	--	52.8	813	4.6	50.0	50.0	-1.8
Ration I	15	3990	52.8	--	--	52.8	708	4.5	50.0	45.0	+3.3
Average						52.3		4.3		48.5	- .5

Ration II	4	4333	188.0	—	—	188.0	765	2.5	50.0	175.0	+10.5
Ration II	5	4333	188.0	—	—	188.0	770	3.6	50.5	181.8	+2.6
Ration II	6	4333	188.0	—	—	188.0	705	2.4	50.0	180.0	+5.6
Ration II	7	4333	188.0	—	—	188.0	734	1.3	51.0	188.7	-2.0
Ration II	10[1]	4333	188.0	—	—	188.0	724	4.7	50.0	160.0	+23.3
Ration II	14	4333	188.0	—	—	188.0	721	4.1	50.0	165.0	+18.9
Average						188.0		2.8		178.1	+7.1
Experiment 2 Trial II											
Ration I	3	4639	66.0	—	—	66.0	929	1.7	54.4	54.4	+9.9
Ration I	8	4639	66.0	—	—	66.0	918	6.6	50.0	55.0	+4.4
Ration I	9	4639	66.0	49	0.8	65.2	1089	9.5	50.0	50.0	+5.7
Ration I	12	4639	66.0	—	—	66.0	805	2.8	50.0	55.0	+8.2
Ration I	13	4639	66.0	—	—	66.0	956	6.2	50.0	55.0	+4.8
Ration I	15	4639	66.0	—	—	66.0	895	7.2	50.0	55.0	+3.8
Average						65.9		5.7		54.1	+6.1
Ration II	4	5142	256.8	60	4.4	252.4	870	1.6	50.5	242.4	+8.4
Ration II	5	5142	256.8	—	—	256.8	932	3.9	50.5	242.4	+10.5
Ration II	6	5142	256.8	—	—	256.8	852	2.5	51.0	244.8	+9.5
Ration II	7	5142	256.8	—	—	256.8	871	1.4	50.0	240.0	+15.4
Ration II	10[1]	5142	256.8	—	—	256.8	873	4.0	50.0	130.0	+122.8
Ration II	14	5142	256.8	—	—	256.8	872	2.4	50.0	235.0	+19.4
Average						255.9		2.4		240.9	+12.6

[1]Number 10 not included in average values.

TABLE XXVII

Digestion Coefficients of Lambs on a Normal Ration and on a Ration High in Protein and Potassium

Experiment 1	Sheep Number	Dry Matter	Organic Matter	Protein
Ration I	3	82.33	83.92	78.70
	8	78.61	80.40	75.69
	9	73.44	75.26	71.67
	12	77.15	79.12	72.58
	13	70.51	72.97	67.01
	15	76.88	78.77	72.48
Average		76.49	78.41	73.02
Ration II	4	71.26	72.36	86.86
	5	66.79	67.52	84.32
	6	73.69	74.87	86.34
	7	63.98	66.26	77.46
	11	49.26	52.08	69.82
	14	71.78	72.47	86.31
Average		66.13	67.59	81.85
Experiment 2 Trial I				
Ration I	3	82.36	84.25	78.93
	8	77.92	80.51	69.18
	9	78.52	80.80	68.14
	12	82.71	84.81	79.12
	13	79.62	81.98	72.96
	15	82.26	84.25	78.53
Average		80.56	82.77	74.48
Ration II	4	82.34	83.38	91.22
	5	82.23	83.33	91.29
	6	83.73	84.44	92.34
	7	83.06	84.08	91.71
	10	83.29	84.34	90.44
	14	83.36	84.36	91.92
Average		83.00	83.99	91.49

TABLE XXVII (cont'd)

Experiment 2 Trial II	Sheep Number	Dry Matter	Organic Matter	Protein
Ration I	3	79.97	81.86	73.36
	8	80.21	82.49	75.43
	9	76.27	78.58	62.63
	12	82.65	84.56	78.37
	13	79.39	81.70	71.11
	15	80.71	82.83	74.39
Average		79.87	82.00	72.55
Ration II	4	82.88	83.65	91.91
	5	81.87	82.87	91.38
	6	83.43	84.08	92.50
	7	83.06	83.96	91.88
	10	83.02	83.94	91.88
	14	83.04	83.94	92.11
Average		82.88	83.74	91.94

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