THE INFLUENCE OF UREA IN THE DIET OF LAMBS UPON THE RETENTION OF CALCIUM, PHOSPHORUS, AND NITROGEN, AND UPON THE DIGESTIBILITY OF THE FATTENING RATION

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INTRODUCTION

The possibility of using urea as a source of protein in the rations of ruminants has long been recognized. Many investigators, during the past thirty-five years, have demonstrated the feasibility of this premise. Many of the earliest of the investigations were conducted in Germany where the results obtained were similar in character to those obtained by subsequent and extensive investigations in this country.

Results of these investigations, as published, were not conclusive enough to encourage the use of urea on a commercial basis and interest in the chemical lagged until the outbreak of the recent world conflict when the shortage of naturally occuring protein supplements again focused the attention of investigators on the possibility of using the synthetic product as a source of nitrogen in the ration.

The majority of investigators have concerned themselves with determining whether or not urea can be used by ruminant animals as a source of supplementary nitrogen. They have also been interested in the maximum and optimum levels at which it could be included in the diet. Very little study has been made on the possible effects dietary urea might have on the metabolic processes of the animal body.

REVIEW OF LITERATURE

Armsby (1911) was one of the first to review the literature on the subject of protein synthesis from the nitrogen of urea. He concluded that microorganisms in the rumen were able to synthesize protein from the nitrogen of non-protein substances.

The German investigators Morgen, Scholer, Windheuser, and Ohlmer (1921) were the first to do any comprehensive investigation into the possible effects of including urea in the rations of growing animals and in the rations of lactating animals. They worked with sheep and concluded that age and the metabolic efficiency of the individual animal played a considerable part in determining the efficiency with which that animal will utilize urea. They also concluded that urea could be successfully included in the ration of growing or of lactating sheep to the extent of thirty to forty percent of the total protein of the ration, provided that the original ration contained an adequate amount of protein. Johnson, Hamilton, Mitchell, and Robinson (1942) worked with growing lambs and found that at levels of ten to fourteen percent protein equivalent, a ration containing urea had a higher digestion coefficient than a basal ration containing the same level of protein equivalent. However at a level of seventeen to eighteen percent protein equivalent there was a difference in favor of the basal ration. Despite the favorable digestion coefficient obtained at the ten to fourteen percent level, they concluded that urea cannot be synthesized into protein rapidly enough to meet the needs of growing lambs.

Bartlett and Cotton (1938) in working with young dairy heifers concluded that, for all practical purposes, urea was as well utilized as was the protein from natural protein sources and produced very similar gains to those that result from the feeding of natural protein. Hart, Bohstedt, Deobald, and Wegner

(1938) investigated the possibility of using ammonium bicarbonate and urea as a portion of the protein supplement in the ration of growing calves. They concluded that urea could be satisfactorily used as a portion of the protein supplement particularly when some starch or sugar was included in the ration to enhance the utilization of urea nitrogen. Histological examination indicated that feeding urea at high levels had pathological effects upon the liver, spleen, and kidney.

Working with high producing dairy cows, Archibald (1944) concluded that the inclusion of urea in the ration at a level of twenty-five percent of the total protein equivalent in the ration, produced no significant difference in milk yields from the check group. However the general physical condition of the check group improved during the entire experiment while the general physical condition of the cows on the urea ration declined. Rupel, Bohstedt, and Hart (1943) sought to determine the extent of utilization of urea by dairy cows for milk production. They concluded that urea was utilized, that a readily fermentable carbohydrate increased utilization, and that urea should be fed at a level below that which would provide forty-three percent of the nitrogen ingested. Willett, Henke, and Maruyama (1946) worked with high producing dairy cows and concluded that the dairy cow does not produce milk as efficiently when fed a ration containing urea as when fed only a natural protein supplement. They also concluded that the inclusion of cane molasses in the ration containing urea, had no detrimental effect upon the synthesis of protein from urea.

Briggs, Gallup, Darlow, Hillier, Kinney, Harris, Stephens, Hoefer, and Campbell (1945) concluded under the conditions of a metabolism trial that urea containing pellets were satisfactory as a protein supplement. In their study twenty-five percent of the protein equivalent of the pellet was supplied by urea and the pellet used to balance a basal fattening ration of corn and prairie hay.

Harris and Mitchell (1941) studied urea from the standpoint of body maintenance and growth and concluded that urea nitrogen could replace about ninety percent of the endogenous nitrogen loss in sheep. Sachs (1944) recommended urea as a partial protein supplement and recommended feeding at a three percent level in the concentrate mixture.

Harris, Work, and Henke (1943) demonstrated that steers do not utilize urea nitrogen at a level of six percent of the total ration as well as they utilize the nitrogen from soybean meal at an equivalent rate of intake. Dinning (1946) worked with metabolism steers and concluded that when fed at frequent intervals, urea may satisfactorily substitute for twenty-five percent of the nitrogen in cottonseed meal. He also concluded that there is some indication that urea nitrogen is not as well utilized when fed on alternate days as when the same daily amount is fed at the rate of two feedings daily.

Darlow, Heller, Campbell, Hillier, and Hoefer (1945) worked with two-year-old steers in a wintering experiment and concluded that both soybean cake and cottonseed cake were superior to urea pellets in which twenty-five percent of the nitrogen in the pellets came from the urea, in producing winter gains. Briggs, Gallup, Darlow, Hillier, Kinney, Harris, Stephens, Hoefer, and Campbell (1945) concluded that yearling heifers were wintered as satisfactorily on pellets containing twenty-five percent of their protein (nitrogen) in the form of urea, as when all of the protein was furnished by cottonseed meal.

In a fattening experiment at the Oklahoma Station, Briggs, Gallup, Darlow, Hillier, Kinney, Harris, Stephens, Hoefer, and Campbell (1945) concluded that urea pellets containing twenty-five percent and fifty percent urea nitrogen respectively, were equal to cottonseed meal in fattening young steers.

Mills, Booth, Bohstedt, and Hart (1942) used the rumen fistula technique and demonstrated that urea is not satisfactorily utilized when fed in a ration very low in readily fermentable carbohydrate. An addition of starch to such a ration increased the utilization of urea, but they further observed that the addition of casein to the ration containing urea and starch prohibited the synthesis of urea into protein. In an earlier study Wegner, Booth, Bohstedt, and Hart (1941) had used similar rumen fistula technique to study the influence of the level of protein in the ration upon the utilization of urea. They concluded that when the percentage of protein in the rumen becomes greater than twelve percent, the utilization of urea nitrogen for the production of protein begins to decrease. They also concluded that when the level of protein in the ration becomes greater than eighteen percent, conversion of added urea nitrogen into protein decreases. Mills, Lardinois, Rupel, and Hart (1944) used the rumen fistula technique and demonstrated that the inclusion of corn molasses in the ration increased the activity of the rumen flora and also increased the utilization of urea. They concluded that starch in the ration produced better results than did molasses and that in growing calves urea and cane molasses in the ration caused sub-normal growth but that the addition of either starch or casein to the urea-cane molasses ration gave normal results.

EXPERIMENTAL OBJECTIVES

This study was designed, primarily, to determine the influence of urea upon the metabolism of the calcium and phosphorus in the ration. Data were also obtained on the influence of ingested urea upon the nitrogen balance of lambs and upon their ability to digest other nutrients from a ration which contained urea.

EXPERIMENTAL PROCEEDURE

This study was composed of two experiments. One of which was conducted in the winter of 1945-46 and the other which was conducted in the winter of 1946-47.

First Experiment

In the first experiment the ration used was designed to provide the minimum calcium and phosphorus requirements of the lambs. It was assumed that the influence of urea on the metabolism of these elements in the ration would be more readily noticeable at a minimum intake level than it would be if optimum levels of the two minerals were fed. Corn and corn gluten meal were used as the concentrates in this ration in order to provide an adequate level of readily available carbohydrates and protein and still keep down the mineral intake. Cottonseed hulls were used as the roughage because of their physical characteristics which make them suitable to the feeding conditions contingent to this experiment. Table 1. gives the ration components of each ration fed and the amount of each component fed daily.

TABLE 1. THE COMPOSITION OF THE RATIONS FED LAMBS IN THE FIRST EXPERIMENT

Component	Ration			
	A		B	
	grams	percent	grams	percent
Cottonseed hulls	454	48.8	454	48.0
Corn gluten meal	136	14.6	136	14.4
Corn (yellow)	340	36.6	340	36.0
Urea	——	——	15	1.6

In this experiment eight grade Rambouillet wether lambs were used, which weighed an average of about sixty-five pounds at the start of the experiment. Each lamb was on trial once on ration A and once on ration B. The collection periods were of twenty days duration. A preliminary feeding period of similar duration preceeded each trial. Four lambs were on collection at one time. Two lambs were receiving ration A and two receiving ration B. At the same time the remaining four lambs were on preliminary rations for the succeeding trial and two were receiving ration A and two receiving ration B. Table 2. gives the ration received by each lamb during each twenty day period of the experiment.

TABLE 2. THE FEEDING SCHEDULE USED IN THE FIRST EXPERIMENT WITH LAMBS

	Collection Period			
Lamb Number	1	2	3	4
	ration	ration	ration	ration
1486	A	B'	B	A'
1487	B	A'	A	B'
1489	A	B'	B	A'
1490	B	A'	A	B'
213	A'	A	B'	B
214	B'	B	A'	A
1491	A'	A	B'	B
1492	B'	B	A'	A

' – on preliminary ration.

Metabolism cages used in this study consisted of wooden cages with both sides and the back completely closed. The front was completely closed except for openings which allowed the lambs access to feed and water which was placed in containers on the outside of the cages. Such an arrangement materially assisted in preventing contamination of the urine and feces. The bottom of the cages consisted of three-quarter inch mesh, steel hardware cloth, which allowed the urine and feces to pass through and be collected below. The feces were stopped on a removable screenwire panel and the urine was caught below the panel on a copper pan with all sides sloping toward a spouted opening in the center; beneath the opening a wide-mouthed gallon jar was placed to catch the urine.

Lambs on preliminary rations were kept in small, individual stalls built especially for this purpose. All lambs were fed twice daily and at approximately the same time each night and morning. Urine and feces collections were made at twenty-four intervals at the time of the night feeding.

The daily urine collection for each lamb was measured to the nearest milliliter and a ten percent aliquot was taken. These aliquots were treated with concentrated HCl to prevent the calcium from precipitating out and were stored in airtight containers. The aliquots were kept refrigerated to prevent bacterial action. The HCl was added to each container at the rate of five milliliters per day for the first five days of each collecting period; after which no more was added during the remainder of the period.

The daily fecal collection for each lamb was dried in an electric oven for twenty-four hours and stored in an airtight container. At the end of the collecting period the entire feces collected of a lamb was weighed, an aliquot taken, and the aliquot stored in an airtight container until chemical analyses could be completed.

The ration components were sampled at regular intervals throughout the experiment. The average analyses of the feeds used in the first experiment are given in Table 3.

TABLE 3. THE AVERAGE ANALYSES OF FEEDS USED IN THE FIRST EXPERIMENT

Feed	Daily Amount (gms)	Dry Matter	Composition of Dry Matter								
			Organic	Protein	Fat	Crude Fiber	Nitrogen Free Extract	Nitrogen	Ash	Calcium	Phosphorus
Cotton-seed Hulls	454	87.8	97.5	4.1	1.6	45.0	46.7	0.7	2.5	.169	.045
Corn Gluten Meal	136	91.2	96.4	50.1	2.0	3.9	40.3	8.0	3.6	.172	.599
Corn	340	88.8	98.5	8.7	5.1	2.1	82.6	1.5	1.4	.010	.315
Urea	15	100.0	100.0	288.0	...	....	....	46.1	...	....	....

Second Experiment

In conducting the second experiment, during the winter of 1946-47, the same proceedure was followed as was followed in the previous experiment and the same equipment was used. The experimental animals were eight, "western", wether lambs which averaged about sixty pounds per lamb initially.

The rations fed in the second experiment were the same as those given in Table 1. It was originally planned to feed the same amounts as in the previous experiment but it was found necessary to reduce the original amounts because the lambs refused to consume that much feed. Each component, except urea, was reduced to two-thirds that fed in the first experiment. The urea was fed at the original level. Table 4. gives the ration components of each ration fed and the amount of each component fed daily.

TABLE 4. THE COMPOSITION OF THE RATIONS FED IN THE SECOND EXPERIMENT

Component	Ration			
	A		B	
	Grams	Percent	Grams	Percent
Cottonseed hulls	340	48.7	340	47.7
Corn gluten meal	102	14.6	102	14.3
Corn (yellow)	256	36.7	256	35.9
Urea	——	——	15	2.1

Table 5. gives the ration received by each lamb during each twenty day period of the experiment.

TABLE 5. THE FEEDING SCHEDULE USED IN THE SECOND EXPERIMENT WITH LAMBS

	Trial			
Lamb No.	1	2	3	4
	ration	ration	ration	ration
1270	A	B'	B	A'
1280	B	A'	A	B'
1290	A	B'	B	A'
1300	B	A'	A	B'
1424	A'	A	B'	B
1427	B'	B	A'	A
1438	A'	A	B'	B
1475	B'	B	A'	A

During the second experiment, two milliliters of concentrated HCl were added daily to the urine collection jars in lieu of the twenty-five milliliters added to the aliquot containers in the first experiment. The daily feces collections were stored in airtight containers after being dried in an electric oven. The proceedure followed in handling the urine and feces collections was the same as that followed in the previous experiment.

The ration components were sampled daily and these samples chemically analyzed. Average analyses are given in Table 6.

TABLE 6. THE AVERAGE ANALYSES OF FEEDS USED IN THE SECOND EXPERIMENT

Feed	Daily Amount (gms)	Dry Matter	Composition of Dry Matter								
			Organic	Protein	Fat	Crude Fiber	Nitrogen Free Extract	Nitrogen	Ash	Calcium	Phosphorus
Cotton-seed Hulls	340	91.2	97.0	4.6	1.5	47.9	43.0	0.7	3.0	.208	.050
Corn Gluten Meal	102	94.6	97.4	46.3	1.9	3.5	45.6	7.4	2.6	.175	.360
Corn	256	87.7	98.6	10.4	5.4	1.9	80.8	1.7	1.5	.014	.305
Urea	15	100.0	100.0	292.0	...	....	....	46.7	...	....	....

EXPERIMENTAL RESULTS

First Experiment

The apparent digestion coefficients secured in this experiment are presented in Table 7. Each lamb used in the experiment received both rations once. The calcium, phosphorus, and nitrogen retentions of each lamb were obtained for each ration and are given in Table 8.

A nutritional deficiency, manifesting itself in the form of a stiffening of the joints in the forelegs and a lack of muscular control of the forelegs resulting in inability to stand, began to develop during the third trial period. One lamb was removed from the experiment during the third trial. Following the experiment the lambs were continued on the experimental rations and two more developed marked stiffness. All exhibited the above mentioned symptoms to such a degree that they were of little value as test animals. A period of gradually decreasing feed consumption preceeded each manifestation of the deficiency. The animals afflicted failed to respond to the addition of irradiated dry yeast in the ration at the rate of one gram per lamb per day. They also failed to respond to the addition of alfalfa leaf meal to the ration at the rate of fifteen grams per lamb per day. After these measures failed to induce any response from the lambs, the lambs were put out on green pasture and within ten days all apparent symptoms of the deficiency, except the thinness of body, disappeared.

TABLE 7. THE INFLUENCE OF UREA ON THE APPARENT DIGESTIBILITY OF LAMB RATIONS

Lamb No.	Protein Digestion Coefficient For Ration		Fat Digestion Coefficient For Ration		Nitrogen-Free Extract Digestion Coefficeint For Ration		Crude Fiber Digestion Coefficient For Ration		Organic Dry Matter Digestion Coefficient For Ration	
	A	B	A	B	A	B	A	B	A	B
1486	55.1	63.2	80.0	77.1	78.2	76.9	52.5	50.3	69.2	67.4
1487	61.9	78.4	83.9	86.4	77.1	84.4	56.7	60.9	70.3	78.1
1489	53.5	61.8	79.0	74.7	72.8	75.1	50.3	56.3	66.3	67.1
1490	53.3	65.4	80.1	81.0	70.6	77.1	51.7	53.6	63.5	68.0
214	48.3	63.9	79.3	81.8	64.9	73.5	38.8	38.5	56.2	62.9
1491	46.8	67.6	79.0	77.5	71.9	75.5	37.7	56.5	60.7	68.4
1492	54.8	59.3	75.0	80.2	74.4	73.2	53.8	37.8	66.4	61.8
Average Coefficient	53.3	65.7	79.5	79.8	72.8	76.5	48.8	50.6	64.7	67.8

TABLE 8. THE DAILY CALCIUM, PHOSPHORUS, AND NITROGEN BALANCE (GRAMS) OF LAMBS FED THE EXPERIMENTAL RATIONS IN THE FIRST EXPERIMENT

	Calcium Retention		Phosphorus Retention		Nitrogen Retention	
Lamb No.	A	B	A	B	A	B
1486	.01	-.25	.52	.06	5.73	5.50
1487	-.14	.03	.24	.65	4.60	8.56
1489	-.17	-.30	.14	-.01	6.07	5.26
1490	-.18	-.16	.15	.10	3.87	7.30
214	-.04	-.29	.16	.25	3.59	5.24
1491	-.52	-.29	-.02	.01	2.62	5.05
1492	-.11	-.15	.17	.28	4.89	5.48
Average	-.164	-.201	.196	.189	4.48	6.06

Second Experiment

The apparent digestion coefficients secured in this experiment are presented in Table 9. Each lamb used in the experiment received each of the two rations once.

The calcium, phosphorus, and nitrogen retentions of each lamb were obtained for each ration and are given in Table 10.

In the second experiment, conducted during the winter of 1946-47, vitamin A and D feeding oil was included in both of the rations from the beginning of the experiment. One milliliter of oil per lamb was fed daily and the oil had a potency of four thousand USP units of vitamin D and twenty thousand USP units of vitamin A per gram. No nutritional deficiency was observed at any time throughout the entire experiment.

TABLE 9. THE INFLUENCE OF UREA ON THE APPARENT DIGESTIBILITY OF LAMB RATIONS

Lamb No.	Protein Digestion Coefficient For Ration		Fat Digestion Coefficient For Ration		Nitrogen-Free Extract Digestion Coefficient For Ration		Crude Fiber Digestion Coefficient For Ration		Organic Dry Matter Digestion Coefficient For Ration	
	A	B	A	B	A	B	A	B	A	B
1270	55.0	61.4	84.0	69.6	71.8	67.3	48.6	31.7	64.1	56.1
1280	42.8	71.2	76.6	83.4	70.2	74.3	31.8	53.7	56.9	67.7
1290	57.9	61.7	85.0	78.3	72.6	70.3	56.3	32.8	68.5	58.4
1300	37.3	74.6	75.0	84.8	58.1	75.0	17.2	60.1	45.7	69.8
1424	36.5	57.5	79.1	82.1	52.6	66.4	18.9	22.2	42.7	52.9
1427	40.8	60.5	80.3	79.1	69.9	68.7	32.9	39.7	57.2	58.8
1438	41.2	60.8	75.9	77.5	63.3	68.9	33.5	28.4	53.2	56.4
1475	41.5	60.9	80.3	75.4	68.1	66.7	29.9	34.8	55.4	56.4
Average	44.1	63.6	79.5	78.8	65.8	69.7	33.6	37.9	55.5	59.6

TABLE 10. THE DAILY CALCIUM, PHOSPHORUS, AND NITROGEN BALANCE (GRAMS) OF LAMBS FED THE EXPERIMENTAL RATIONS IN THE SECOND EXPERIMENT

	Calcium Retention		Phosphorus Retention		Nitrogen Retention	
Lamb No.	A	B	A	B	A	B
1270	-.47	0	.003	-.04	3.76	3.31
1280	-.37	-.31	-.22	-.11	4.03	6.33
1290	-.20	-.08	.18	.04	3.58	3.58
1300	-.06	-.56	-.32	-.02	3.80	4.39
1424	-.63	-.33	-.39	-.20	0.78	2.66
1427	-.33	-.45	.01	-.25	0.99	1.80
1438	-.11	-.16	-.06	.15	1.71	3.90
1475	-.12	-.34	.03	-.64	1.62	2.12
Average	-.286	-.279	-.096	-.134	2.54	3.51

DISCUSSION

The lambs in the first experiment did not readily consume the full amount of the rations fed. This was especially true of the cottonseed hulls which were fed as the roughage. The percent of the total ration consumed daily, steadily decreased throughout the entire experiment. Any refused feed was analyzed and deducted from the amount offered, in determining the intake and in calculating the digestion coefficients. In the second experiment the lambs ate the entire amount fed, daily, with apparent relish.

The data presented in Tables 7. and 8. for the first experiment and in Tables 9. and 10. for the second experiment were analyzed for the significance of the difference between means by the method described by Snedecor (1937) and the results of this analysis are given in Table 11.

Ration A in each experiment contained cottonseed hulls, corn, and corn gluten meal. Ration B fed in each experiment was the same except that in each experiment the latter ration contained fifteen grams of crystalline urea.

Almost without exception, the lambs were in negative calcium balance throughout both experimental periods. The irregular retention of calcium as shown in Tables 8 and 10. and the analyses of variance given in Table 11. indicate that the metabolism of calcium is not influenced by the inclusion of urea in the ration.

The retention of phosphorus was also irregular and there was very little variance between the two rations in either of the experiments. In the first experiment the lambs were in positive balance in all but a few instances while the opposite was true of the second experiment.

The results obtained in this study indicate that the addition of urea to a fattening ration did not materially influence the retention of either calcium or phosphorus. This indicates that urea can be safely added to rations low in both calcium and phosphorus without upsetting the metabolic process of these elements. Before this experiment was conducted it was thought metabolism might be conditioned by changes in the pH of the digestive tract which might result from adding urea to the ration.

In both experiments the average storage of nitrogen was greater for ration B than for ration A. Table 11. shows that these differences were statistically significant. It may be concluded from this experiment that the addition of urea to a fattening ration increases the storage of nitrogen even though the urea was included in addition to the calculated protein requirements of the lamb. The basal ration, or ration A, had an estimated nutritive ratio of 1:7.1 in the first experiment and 1:7.0 in the second experiment. Morrison (1945) suggests a nutritive ratio of 1:6.7-7.2 for lambs of the weight of those used in these experiments. In calculating the nutritive ratios of the experimental rations the digestion coefficients given by Morrison (1945) were applied to the chemical composition of the feeds used in these experiments. In the first experiment the basal ration or ration A contained 11.3 percent protein on an air dry basis and ration B contained 15.6 percent protein equivalent (N.x6.25). In the second experiment the protein contents of rations A and B were 11.8 and 17.7 percent, respectively.

Ration B, containing the urea, had a protein digestion coefficient of 65.7 percent in the first experiment and 63.6 percent in the second experiment as compared to 53.3 percent and 44.1 percent respectively for ration A. These differences of 12.4 percent and 19.5 percent, respectively in apparent digestion coefficients of crude protein when urea is added to the ration, are highly significant as shown in Table 11. These findings are in agreement with the findings of the Oklahoma Station in previous metabolism studies and with the findings of Johnson and others (1942) that the nitrogen in urea rations is highly digestible. This experiment therefore confirmed these observations that the addition of urea to a ration increases the digestibility of the protein equivalent of the ration.

As indicated in Table 11, there was no significant difference between the two rations in the digestibility of fat. The minor differences that were observed impress one as being unimportant when it is noted that the difference was in favor of ration B in the first experiment and in favor of ration A in the second experiment.

The average apparent digestion coefficient for the crude fiber, while consistently lower for ration A, was not of significant difference in the first experiment or second experiment. The consistency with which these differences occurred indicates that there is a slightly more efficient digestion of crude fiber when urea is included in the ration. However, further investigation is necessary before arriving at a definite conclusion concerning this tendency.

In both the first and second experiments the apparent digestibility of nitrogen-free extract and of organic dry matter was higher for ration B than for ration A. The data contained in Table 11. indicates that the differences are not significant but here again the consistency with which the differences occur casts doubt that conclusions are justified without further investigation.

TABLE 11. THE INFLUENCE OF ADDITIONS OF LAMB FATTENING RATION ON THE DIGESTIBILITY AND STORAGE OF NUTRIENTS.

	Digestion Coefficients (percent)					Nutrients Retained Daily (grams)		
Rations Compared	Protein	Fat	Crude Fiber	Nitrogen Free Extract	Organic Dry Matter	Calcium	Phosphorus	Nitrogen
A and B (First experiment)	12.4**	0.3	1.8	3.7	3.1	-0.037	-0.007	1.58*
A and B (Second experiment)	19.5**	0.7	4.3	3.9	4.1	-0.007	-0.038	0.97**

* Significant at the 0.05 point.
** Significant at the 0.01 point.
Unmarked is not significant.

SUMMARY

In two digestion and retention studies, fifteen grams of crystalline urea were added to a ration consisting of shelled corn, corn gluten meal, and cottonseed hulls. The basal ration contained 11.3 percent protein in the first study or experiment and 11.8 percent protein in the second experiment. The rations containing the urea contained 15.6 percent protein equivalent in the first experiment and 17.7 percent protein equivalent in the second experiment. The addition of urea to the basal rations did not change calcium and phosphorus intakes of the lambs.

Both the basal rations and those supplemented with urea resulted in negative balances of calcium. The magnitude of the daily loss was not influenced by the addition of urea to the basal rations. Both the basal and urea supplemented rations resulted in positive balances of phosphorus in the first experiment and in negative balances in the second experiment. In neither of the experiments were the differences significant. Nitrogen storage was higher in the ration containing urea in both experiments and when this difference was treated statistically it was found to be significant in the first experiment and highly significant in the second experiment.

The ration containing urea had higher apparent digestion coefficients for protein, fat, crude fiber, nitrogen-free extract, and organic dry matter than did the ration without urea. The difference for protein was a highly significant difference in both of the experiments conducted. The difference in the digestibility of the other nutrients was not significant in either study.

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