THE UTILIZATION OF UREA BY SHEEP

By

L. S. POPE

Bachelor of Science, 1947

Michigan State College

East Lansing, Michigan

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Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

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THESIS AND ABSTRACT APPROVED:

C. P. Whitehair
Thesis Adviser

A. E. Darlow
Faculty Representative

D. C. McIntosh
Dean of the Graduate School

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INTRODUCTION

Nearly 60 years have elapsed since German scientists first demonstrated that the ruminant can utilize non-protein nitrogen by virtue of the microbial flora of the paunch. Since that time, much research has been devoted to the use of urea as a means of extending critical protein supplies.

This research, together with periodic shortages of protein supplements, has resulted in a tremendous increase in the use of urea in livestock feeds during the last half-century. In Europe, during the year 1936, the use of urea as a feed ingredient reached a level of 10,000 tons. In the United States and Canada, increasing use has been made of urea in commercially prepared feeds as a means of maintaining crude protein standards while reducing feed costs. In areas where grass and roughage are abundant, but protein supplements are often in short supply, it is possible that urea can greatly reduce animal production costs. Such an area is the southwest, where protein deficiencies frequently occur in cattle and sheep during the winter months.

While our knowledge of the factors affecting urea utilization has greatly increased through experimental research, much of this work has lacked a practical application. It is necessary that we know more about the actual feeding value of urea, as well as its limitations, in a wide variety of rations and under varying systems of cattle and sheep production. Since the utilization of urea is a function of the paunch microorganisms, a favorable rumen environment is essential for most efficient use of this substance.

In this investigation, the effect of certain ration factors on urea utilization was studied. In practical feeding trials, the value of urea was compared to that of cottonseed meal in rations for ewes during pregnancy and lactation, as well as in rations for growing and fattening lambs.

REVIEW OF LITERATURE

Armsby (1911) reviewed the early experimental work on the value of urea and other nitrogenous compounds as protein substitutes for ruminants. He concluded that when the protein level of the ration is low, and other conditions favorable, non-protein nitrogen can partially replace natural protein feeds for maintenance, and possibly for growth and milk production. It was his belief that the protein synthesized by the rumen bacteria was of inferior quality, but that the addition of non-protein nitrogen might increase the performance of ruminants fed protein deficient rations.

Mitchell and Hamilton (1929) have reviewed the early experimental work on urea, as have McNaught and Smith (1947) and Elsden and Phillipson (1948). Krebs (1937) published an extensive review of the literature on non-protein nitrogen utilization and concluded that although there was evidence that bacterial protein synthesis took place in the rumen, the quantity of protein synthesized was small and of little benefit to the ruminant.

Growth Studies as a Means of Evaluating Urea Utilization

Hart and associates (1939), at Wisconsin, were among the first in America to study urea utilization. They conducted long-term growth studies with Holstein calves fed a low-protein ration of timothy hay, corn, starch and molasses (containing about 6 per cent total protein), and the same ration supplemented with urea, ammonium carbonate or casein. The addition of each of the nitrogenous supplements raised the total protein level of the ration to approximately 18 per cent. The following weight gains were obtained with bull calves over a 40-week growing period: basal ration, 201 pounds; urea supplemented ration, 290 pounds, and the casein supplemented ration, 427 pounds. In a further study, heifer calves fed a similar ration supplemented with equivalent amounts of urea or casein nitrogen gained an average of 1.3 pounds per day on the urea ration and 1.5 pounds daily on the casein ration.

Watson and associates (1949), in Canada, combined growth studies and carcass analyses to measure the increase in body protein of steers and lambs fed low-protein rations supplemented with urea or casein. In one test, 30 steers were divided into five groups. Two steers of each group were slaughtered at the beginning of the experiment and their carcasses analyzed for protein, fat and ash. Of the remaining three steers in each group, one was fed the low-protein ration, one the low-protein ration plus urea, and one the low-protein ration plus casein. After a growth period of 40 to 50 weeks, the remaining steers in each group were slaughtered and their carcasses analyzed. Results obtained show that the carcasses of steers fed rations supplemented with either urea or casein contained a greater quantity of body protein, fat and ash as compared to steers fed the basal ration. However, casein was definitely superior to urea as a source of nitrogen when measured either by gains in weight during the feeding period or carcass composition.

Similar experiments with 60 lambs, by these same authors, were inconclusive due to numerous feed refusals. The data obtained did indicate that lambs fed the urea-supplemented rations stored more protein in the form of wool growth than lambs fed the basal ration.

Harris and Mitchell (1941a) conducted an experiment with 15 to 18-month-old wethers to determine whether the rate of conversion of urea nitrogen to bacterial protein was sufficient to meet the maintenance requirements of the sheep. They found that the wethers could be maintained in body weight and nitrogen equilibrium for more than 100 days on rations in which urea supplied nearly 90 per cent of the nitrogen. To maintain these wethers in nitrogen equilibrium required daily intakes of 202 mg. of urea nitrogen, as compared to only 161 gm. of casein nitrogen per kilogram of body weight. At the nitrogen equilibrium point, the biological value of the protein of the urea ration was 62, as compared to 79 for the casein ration.

In further studies with growing lambs, Harris and Mitchell (1941b) found that the addition of urea to a basal ration which had been proven to be inadequate, converted it into a ration capable of supporting nearly normal growth. They concluded that when the protein level of the ration exceeds 11 per cent, bacterial synthesis of protein from urea nitrogen is retarded. With the percentage of nitrogen in the ration supplied by urea remaining the same, they found that rations containing 8, 11, and 15 per cent protein had biological values of 74, 60, and 44, respectively.

From these growth and maintenance studies, it would appear that although the utilization of urea by cattle and sheep fed nitrogen-poor rations has been conclusively demonstrated, its value is distinctly less than that of a natural protein, such as casein, when fed in nitrogen equivalent amounts.

Nitrogen Balance Studies and their Contribution to the Knowledge of Bacterial Protein Synthesis

Johnson et. al. (1942) studied the efficiency of urea utilization in rations containing 10, 12, and 14 per cent total protein in nitrogen balance studies with lambs. They concluded that the addition of urea to a basal ration containing about 6 per cent crude protein, sufficient to raise the total protein level to 12 per cent, resulted in a retention of nitrogen which could not be improved by further additions of urea. However, nitrogen retention beyond this level could be increased by additions of soybean meal nitrogen. When urea and soybean meal were each used to increase the total protein content of the basal ration to 16 per cent, soybean meal was much superior to urea as a source of nitrogen.

Hamilton, Robinson and Johnson (1948) concluded that urea is a satisfactory source of nitrogen for growing lambs provided (1) at least 25 per cent of the nitrogen in the ration is in the form of preformed protein, and (2) the total protein content of the ration is above the minimum requirements of the ruminant, but does not exceed a level of approximately 12 per cent. In their work with lambs, the nitrogen in a ration containing 16.2 per cent protein (with 63 per cent of the nitrogen supplied by urea) was less efficiently utilized than the nitrogen in a ration containing 11.4 per cent protein (with 46 per cent of the nitrogen supplied by urea).

Johnson and associates (1944) have shown that lambs treated with a copper sulfate drench to remove the rumen protozoa can utilize urea. From this they concluded that urea utilization is primarily, if not completely, a function of the rumen bacteria. When lambs so treated were fed rations containing 11.2 per cent total protein (83 per cent of the nitrogen supplied by urea) the protein of the ration had a biological value of 49. The bacterial fraction of the rumen ingesta, separated by means of a centrifuge, was found to contain 44.5 per cent protein on a dry basis. When fed to rats, it had a biological value of 66.

It is apparent that the bacterial protein synthesized from urea must be of at least fair quality if ruminants can make considerable growth on rations in which urea supplies most of the nitrogen. Loosli and associates (1949) measured the amino acid composition of the bacterial protein synthesized in the rumen of lambs and goats fed a purified ration nearly devoid of nitrogen other than that supplied by urea. Microbiological assays of the rumen ingesta of lambs fed this purified diet indicated that the essential amino acids were present in relatively high concentrations. Thus microbial synthesis of these amino acids must have taken place. When urea was compared to nitrogen equivalent amounts of casein, biological values of 56 and 82 were obtained for the urea and casein rations, respectively. Lambs fed the urea ration gained an average of 0.23 pounds daily, as compared to 0.30 pounds daily for lambs on the casein supplemented ration.

Loosli and Harris (1945) were the first to show that the addition of a small amount of methionine to rations containing urea increased the rate of gain and nitrogen retention of lambs. Urea rations so supplemented were equivalent to linseed meal rations as measured by the nitrogen balance technique. However, urea without methionine failed to promote as good gains or as high a positive nitrogen balance as linseed meal. Lofgreen, Loosli and Maynard (1947) later confirmed this work. In nitrogen balance studies, they fed lambs a basal ration of corn, timothy hay, sugar and starch, containing about 6 per cent total protein. Urea was added to increase the protein equivalent of the basal ration to 10 per cent, with urea supplying 40 per cent of the total nitrogen. Methionine was added at a level of 0.2 per cent of the total ration, which was somewhat less than the level fed by Loosli and Harris. The addition of methioine to the urea ration significantly increased the percentage of dietary nitrogen retained. It was concluded that the addition of methionine to the urea ration improved the performance of lambs equally as well as equivalent amounts of linseed meal nitrogen. However, the biological value reported for the protein of the linseed meal ration was 76, and for the urea plus methionine ration, 74. In this same study, a protein supplement of dried egg gave a biological value of 86.

Studies Using the Rumen Fistula and the Artificial Rumen

Mills _et_. _al_. (1942) demonstrated that a source of readily available carbohydrate was necessary for most efficient use of urea. Using a fistulated dairy heifer, they measured the protein content of the rumen ingesta when a basal ration of 10 pounds of timothy hay was fed, and compared this to the protein content when 150 grams of urea were added to the ration. They found that when urea was added to the basal ration, hydrolysis of the urea was not complete at the end of one hour, and that about one-half of the ammonia formed from urea remained in the rumen at the end of six hours. The protein level of the rumen ingesta was slightly less than when timothy hay was fed alone. When four pounds of starch and 150 grams of urea were added to the basal ration, analyses of periodic samples from the rumen indicated that urea was completely hydrolyzed within one hour after feeding, and that the ammonia formed had disappeared at the end of six hours. This disappearance of ammonia was associated with a rise in the protein content of the ingesta, which was nearly 57 per cent higher than when timothy hay alone was fed. The authors concluded that when a poor quality roughage constitutes the only source of carbohydrate in the ration, the conversion of urea nitrogen to bacterial protein is very difficult.

Mills and associates (1944), using the rumen fistula technique, compared molasses and starch as sources of energy for rumen microorganisms. A basal ration of timothy hay and molasses resulted in a decreased utilization of supplemental urea as compared to a basal ration of timothy hay and starch. It was concluded that starch was a more suitable substrate than molasses for bacterial conversion of urea nitrogen to protein.

Pearson and Smith (1943) used the rumen fistula technique to study changes in the protein content of the ingesta. Their results also indicated that starch was a more effective carbohydrate than sugar, since bacterial synthesis of protein from urea was less when simple sugars were the only source of readily available energy. In further <u>in vitro</u> experiments, the same authors found that protein synthesis was equal to the ammonia produced by the breakdown of urea only when starch or simple sugars were present. High levels of natural proteins in the ration, such as casein, resulted in an inefficient use of urea, with ammonia formation exceeding the ability of the rumen bacteria to synthesize intracellular protein.

Burroughs and associates (1951a) at Ohio studied the utilization of urea by rumen microorganisms in laboratory cultures. They advanced the theory that the requirements of rumen microorganisms are essentially simple; these being ammonia, a source of energy, and minerals. From their work, they concluded that when urea is present, natural forms of protein are used by the rumen bacteria primarily as a source of energy, rather than as a source of nitrogen. Further, large quantities of ammonia from protein sources compete with the ammonia produced by the breakdown of urea and an inefficient use of urea nitrogen results. Accordingly, the efficiency of urea utilization should be improved when the level of protein in the diet is low, or when it is less subject to bacterial attack due to such factors as insolubility in the rumen medium. This is essentially the same view as presented earlier by Pearson and Smith (1943). Burroughs and associates recognized that natural proteins could also supply mineral elements, in addition to nitrogen and energy, which could aid in bacterial fermentation.

Arias, Burroughs, Gerlaugh and Bethke (1951) studied the energy requirements of the rumen bacteria by the artificial rumen technique. They concluded that rumen bacteria have a specific need for small amounts of readily available energy, such as starch or sugar, when cellulose forms the major part of the carbohydrate in the ration. They felt that this was due to the inability of the rumen bacteria to act rapidly enough on the complex cellulose molecules to obtain sufficient amounts of lower carbohydrates, particularly during the first few hours of fermentation process. However, feeding large amounts of readily available carbohydrate was unwarrantable due to a decrease in cellulose digestion which has been shown to occur under such conditions. They felt that without adequate cellulose digestion, urea utilization continues only for a short fermentation period. Thus a small amount of readily available carbohydrate should promote optimum urea utilization and, in turn, the digestion of the fibrous portion of the ration. This need by the bacteria for a supply of readily available carbohydrate is in line with the early work of Mills et. al. (1942).

In further artificial rumen studies, Burroughs and associates (1951b) were able to show that certain minerals and the ash of a variety of different materials will stimulate urea utilization and cellulose digestion in vitro. They obtained a beneficial response when water extracts of clover meal, rumen ingesta, and manure were added to the medium. Similar responses were obtained with the ash of blackstrap molasses, clover, and timothy hay when each was added on an equivalent ash-weight basis. Their work indicates that iron and phosphorus are of primary importance. However, iron was absent from the mineral mixture added to the fermentation flasks and thus an iron deficiency, due to the purified nature of the ingredients used, was not precluded. Their work would suggest that molasses is an ideal carrier for urea, since both the ash and sugar fractions were found to enhance urea utilization and cellulose digestion.

The Effect of Urea on the Digestibility of Ration Nutrients

The possibility exists that the addition of urea to rations low in protein and consisting primarily of low-quality roughage, improves the digestion of nutrients other than protein in the ration and thereby benefits the ruminant. Harris and Mitchell (1941b) were the first to observe an increase in cellulose digestion upon the addition of urea to low-protein rations for lambs.

Similarly, Briggs and associates (1948) found that the addition of urea to a low-protein ration, in which prairie hay was the roughage, increased the apparent digestibility of the hay nutrients and changed a negative nitrogen balance to one slightly positive.

Glasscock et. al. (1950) conducted an experiment with steers which illustrates the practical application of this point. Eight pairs of steers were used, with two pairs fed a basal ration of prairie hay and five pounds of citrus molasses per head daily. The remaining steers received the same amount of prairie hay and molasses plus varying amounts of urea (equivalent in nitrogen to one and two pounds of cottonseed meal per steer daily). With the prairie hay intake restricted at 4.3 pounds per head daily, the control steers lost an average of 0.91 pounds per head per day over the 70-day experimental period, while the steers fed the urea rations lost only 0.16 pounds. Following this period of restricted hay intake, prairie hay was fed free choice. The control steers continued to lose weight at the rate of 0.60 pounds per head daily, while the urea-fed steers gained 0.75 pounds. During the period of unrestricted hay intake, the control steers consumed an average of 4.9 pounds of hay daily, while the steers receiving urea consumed an average of 11.1 pounds. The addition of urea to this ration increased the appetites of the steers and their ability to digest roughage, but this effect was most beneficial when the roughage intake was unlimited.

Practical Feeding Trials with Urea

Ultimately, the value of urea as an extender of protein supplies must be determined from practical feedlot and range trials. Briggs and associates (1947) found that a pelleted feed of cottonseed meal, hominy feed, molasses and urea, in which urea supplied 25 per cent of the total nitrogen, proved satisfactory as compared to straight cottonseed meal in two drylot studies with fattening steer calves. Pellets containing the same ingredients, but with 50 per cent of the total nitrogen in the form of urea, proved to be unpalatable during the latter part of the fattening period. In two experiments, pellets containing 25 per cent of the total nitrogen as urea were compared to cottonseed cake as supplements for wintering yearling heifers on dry, native grass pastures. When these supplements were fed at a level of 2.35 pounds per head daily, no essential difference was noted in the weight gains of the heifers, or in their apparent thrift or condition.

Ross, MacVicar and Stephens (1950) reported that pellets containing 25 per cent urea nitrogen and 75 per cent cottonseed meal nitrogen were as satisfactory as equivalent amounts of cottonseed cake for wintering three-year-old steers on native grass pastures. However, the authors state that at the levels fed, sufficient nitrogen other than urea was present in the pellets to meet the estimated protein requirements of the steers. This experiment may not have been a critical test of the value of urea under range conditions.

Baker (1950) has summarized 13 wintering and fattening trials with steers and heifers conducted at the Nebraska station during a 7-year period. In these tests, urea was fed in various pelleted feeds which contained either corn, soybean meal, dehydrated alfalfa meal, molasses, or combinations of these feeds. In each comparison, the value of the urea pellets was compared to natural feed supplements supplying equivalent amounts of nitrogen. In nine of the thirteen trials, the natural sources of nitrogen were superior to the urea-containing supplements as measured by gains in body weight. However, these differences were large in only two trials. In four of the thirteen tests, the urea-containing pellets were equal to, or superior to, natural forms of protein. From these results, the author concluded that urea can be successfully used in a wide variety of feeds for cattle.

Beeson and Perry (1951) have shown that steers fed an average daily ration of ground corn cobs ad. lib., 2.25 pounds of soybean meal, 1 pound of molasses feed, minerals and vitamins A and D, made average daily gains of 1.28 pounds. When urea replaced one-third and two-thirds of the soybean meal at nitrogen equivalent levels, daily gains averaged 1.25 and 1.14 pounds, respectively. Their results indicate that urea can be utilized as a source of nitrogen in this type of ration with an efficiency approaching that of soybean meal.

McClymont (1948), in Australia, studied the comparative value of urea and certain natural proteins as supplements for low-protein rations fed to Shorthorn calves. With the ratio of concentrates to roughage in the rations varying from 46:50 to 0:97, average urea utilization was approximately 60 per cent. In arriving at this value, urea utilization was expressed as the ratio of the increased performance of the urea-fed calves over the basal group, to that of the protein-fed calves over the basal group. The efficiency of feed utilization of calves on the urea rations, as compared to calves fed the natural protein rations, averaged 67.5 per cent. McClymont estimated that the feed required per pound of gain was reduced by about 24 per cent due to the addition of urea to the basal ration.

Although numerous nitrogen balance trials have shown that lambs can utilize urea, Willman, Morrison and Klosterman (1946) found that fattening lambs fed urea as the only source of supplmental nitrogen made average gains of 0.26 pounds per day, while lambs fed equivalent amounts of linseed meal nitrogen gained 0.32 pounds per head daily. Sodium sulfate was used in these experiments in an attempt to improve urea utilization, but without success.

Jordan (1950) and Rasmussen (1951), at South Dakota, studied the value of urea in rations for pregnant ewes, as measured by the weight gains of the ewes during 100 days of the pregnancy period. Urea was added to a pelleted supplement at the rate of 5 and 10 per cent of the total feed. Jordan (1950) found that the addition of 0.2 pounds daily of the 5 and 10 per cent urea pellets to a basal ration of brome grass hay for pregnant ewes resulted in as good gains in weight as could be obtained with an equivalent amount of soybean meal. Rasmussen (1951) found soybean meal to be slightly superior to either the 5 or 10 per cent urea pellets when 0.2 pounds of each supplement was added to a basal ration of brome grass hay. Average gains in body weight ranged from 4.5 pounds for ewes fed the soybean meal supplement to -1.9 pounds for ewes fed the 10 per cent urea pellets. The author recognized that the gains obtained with all rations were inadequate to maintain the body condition of the ewes and compensate for the growth of the fetus and fetal membranes.

Hilston and associates (1951), at Wyoming, studied the utilization of urea by pregnant ewes. The addition of urea improved the performance of ewes fed a basal ration of native hay, molasses and yellow corn. However, lambs from ewes so fed were lighter at birth, with a greater percentage of lamb mortality, than from ewes fed nitrogen equivalent amounts of soybean meal.

Summary of the Experimental Work on Urea

It would appear from the literature that the evidence is conclusive that both cattle and sheep can utilize urea to satisfy at least a part of their protein requirements. In the majority of experiments, however, the value of urea has been somewhat less than that of natural protein. The ability of sheep to make efficient use of urea lacks confirmation in practical feeding trials. The experiments of Loosli and Harris (1945), in which a beneficial effect of methionine was indicated, suggests that sheep may have a higher requirement than cattle for certain nutrients in the ration. This may be of special importance during periods of increased demands by the body for nutrients, i. e. with ewes during gestation and lactation, or with lambs making rapid gains in weight. Further research is needed with sheep as to the optimum ration conditions necessary for most efficient use of urea, as well as to its advantages and limitations under practical feeding conditions.

EXPERIMENTAL OBJECTIVES

Experiments were designed to study the value of urea as a nitrogen supplement under the following conditions:

Part I Nitrogen balance and digestion studies with lambs.

Experiment A. The relative value of urea and uramite as supplements to low-protein rations.

Experiment B. The efficiency of urea utilization as affected by the level added to a low-protein ration.

Experiment C. The value of methionine when added to a low-protein ration with and without urea.

Part II The utilization of urea by ewes during pregnancy and early lactation.

Trial I 1949-50 Study

Trial II 1950-51 Study

Part III The utilization of urea by fattening lambs.

PART I

NITROGEN BALANCE AND DIGESTION STUDIES WITH LAMBS

In the majority of metabolism and feeding experiments, the value of urea has been somewhat less than that of natural proteins when fed at nitrogen equivalent levels. If urea is to become a practical feed supplement, it is necessary to increase its value as a source of nitrogen for ruminants. This is especially true when the cost of carbohydrate feeds is high relative to common protein supplements.

It seems possible that a factor contributing to inefficient utilization of urea might be the rapid breakdown of urea to ammonia in the rumen medium under favorable conditions. This rapid release of ammonia may exceed the capacity of the rumen bacteria to synthesize protein. Excess amounts of ammonia may escape the rumen medium by absorption at the rumen wall. It is possible that a modified urea compound, which would break down more slowly, might be more completely utilized.

In studying this phase of the problem of increasing the value of urea, a new product was utilized for metabolism studies. This product, called uramite, contained approximately 38.75 per cent nitrogen. Approximately 63.3 per cent of the nitrogen was insoluble, probably due to the formation of a urea-formaldehyde complex in the synthetic process used. This complex apparently undergoes hydrolysis at a slow rate. In metabolism studies with lambs, urea and uramite were compared as supplements to low-protein rations. Three basal rations were fed which differed in their proportion of roughage (cottonseed hulls) and concentrates. An additional trial was conducted with prairie hay as a roughage. These metabolism studies are designated as Experiment A.

It has been shown that when urea is added to rations containing more than 12 per cent total protein, the efficiency with which it is utilized is decreased. The efficiency of urea utilization when varying amounts were added to a ration containing approximately 7 per cent total protein was determined and compared to the efficiency of a common feed source of nitrogen, cottonseed meal, at two levels of supplementation. These metabolism studies are designated as Experiment B.

It has been shown that the addition of the amino acid, methionine, to rations containing urea increases the utilization of urea nitrogen. It seems possible that this beneficial action of methionine may be due either to its effect on bacterial protein synthesis, or to its action in lowering the level of urinary nitrogen excretion (as shown by Allison, et. al., 1947). To study this problem, methionine was added in varying amounts to low-protein rations supplemented with urea, and to similar basal rations without urea. These metabolism studies are designated as Experiment C.

In addition, in each experiment the effect of the addition of urea on the digestion of the ration nutrients was studied.

Experimental

The experimental procedure employed in all metabolism experiments was essentially the same.

Grade Texas feeder lambs of mixed breeding were used. In Experiment A, the lambs were of fine wool breeding and averaged 66 pounds in weight. The lambs used in Experiments B and C were equally divided between crossbreds and fine wools. The same lambs were used for both experiments.

They averaged 65 pounds in weight during Experiment B and 78 pounds during Experiment C.

Each trial, consisting of a 10-day collection period, was preceded by a 10-day preliminary period. During the preliminary period, the lambs received rations identical to those fed during the collection period. In Experiment A, the lambs were kept in false-bottomed metabolism cages during the preliminary period, while in Experiments B and C they were given access to an exercise pen between feedings and stanchioned in individual stalls to receive their rations.

The collections were made in individual metabolism stalls as designed by Briggs and Gallup (1949). The lambs were weighed before and after each collection period and an average of the two weights used for the period.

Collections of feces and urine were made once daily at the time of the evening feed. The feces were weighed to the nearest gram and an aliquot representing 10 per cent by weight of the daily excretion was placed in a quart jar and preserved under refrigeration until analyzed. The daily urine excretion was measured to the nearest 5 ml. in a large graduated cylinder and a 10 per cent aliquot by volume was taken and preserved in quart jars under refrigeration. Approximately 2 ml. of concentrated hydrochloric acid was added daily to the collection jars beneath the metabolism stalls to insure an acid condition of the urine.

Total urinary nitrogen was determined by the Kjeldahl method on the composite 10-day sample from each lamb. Nitrogen was determined by Kjeldahl analysis on the feces previous to drying. After drying, proximate analyses were made on the fecal material in accordance with the procedure outlined by the Association of Official Agricultural Chemists (1940).

The rations were fed twice daily, one-half the daily allowance at each feeding. With the exception of two rations during Experiment A, and one ration during Experiment C, at least 4 lambs completed trials on each ration.

In Experiment A, the ration ingredients were weighed out at each feeding. The urea and uramite rations were prepared by adding 9.0 grams of urea and 9.75 grams of uramite to the basal rations fed. The urea, or uramite, and minerals were weighed out in small envelopes and added to the ration at the time of feeding.

In Experiments B and C, a 10-day supply of the concentrate portion of the ration (including minerals and urea, where fed) was mixed at the start of each preliminary and collection period. This was stored in covered containers until fed. A sample of the concentrate mixture was taken for analysis, together with a sample of cottonseed hulls, at various times during the collection period. From the analyses, it appeared that this method of preparation of the concentrates resulted in a very uniform mixture which varied only slightly from one trial to another within the same ration. In addition, 1 ml. of fortified codliver oil was fed daily to each lamb with the evening feed to insure an adequate supply of vitamins A and D. The minerals fed were designed to supply the recommended allowances for salt, calcium and phosphorus.

In the calculation of biological values, the Thomas-Mitchell formula was used:

Biological value =

$$\frac{\text{N intake} - (\text{fecal N} - \text{metabolic N}) - (\text{urinary N} - \text{endogenous N})}{\text{N intake} - (\text{fecal N} - \text{metabolic N})} \times 100$$

In computing the metabolic and endogenous nitrogen excretion, the factors proposed by Harris and Mitchell (1941a) were used. They found the metabolic nitrogen excretion of wethers to be 0.555 grams per 100 grams of dry matter intake, and the endogenous nitrogen equal to 0.033 grams per kilogram of body weight. These values were determined by feeding low-protein rations, and agree closely with those proposed by other research workers.

The chemical composition of the rations fed is given with the results of each experiment. The corn used was estimated to be of number 2 quality, and the prairie hay was of good quality and not excessively weathered. The data were subjected to an analysis of variance (Snedecor, 1946).

RESULTS AND DISCUSSION

Experiment A The Urea and Uramite Metabolism Study

The rations fed in Experiment A are shown in Table 1, and their average chemical composition is given in Table 2. The average daily nitrogen balance and biological value data are given in Table 3, with data for individual lambs in Table 27, appendix.

As shown in Table 1, urea and uramite were added to three basal rations containing 84, 49 and 28 per cent cottonseed hulls as the roughage; these rations have been designated as the high-, medium-, and low-hull rations, respectively. Each basal ration contained approximately 6.7 per cent crude protein on a dry matter basis. In the medium- and low-hull rations, corn and starch replaced cottonseed hulls. A fourth ration was prepared by substituting prairie hay for cottonseed hulls at the medium level. Urea and uramite each supplied 3.77 grams of nitrogen when added to the basal ration.

Nitrogen retention on the three basal rations was progressively improved by the replacement of cottonseed hulls with corn and starch. The average daily nitrogen balances obtained with lambs on the high-, medium-, and low-hull basal rations were -0.54, +0.26 and +1.23 grams, respectively. It may be that the improved nitrogen retentions obtained with the medium- and low-hull rations were due to greater digestibility of the protein of these rations. Morrison (1950) uses a digestion coefficient of zero for cottonseed hull protein. That the digestibility of the protein of the roughage in the basal ration affects nitrogen retention is indicated also by the greater average nitrogen balance obtained with the medium-hay ration, +1.48

TABLE 1

Daily Allowance in Grams for Rations Fed Lambs in the Urea and Uramite Metabolism Study

Ingredient[1]	Basal Rations Fed[2]			
	High Hull	Medium Hull	Low Hull	Medium Hay
Cottonseed Hulls	600	350	200	
Prairie Hay				350
Ground Shelled Corn		300	350	300
Cottonseed Meal	50			
Starch	50	50	150	50
Mineral Mixture[3]	15	15	15	15

[1] In addition, each lamb received 1 ml. of fortified codliver oil daily.

[2] The urea rations were made by adding 9.0 grams of "262" feeding compound (containing 42% urea nitrogen) to the basal rations. The uramite rations were made by adding 9.75 grams of uramite to the basal ration.

[3] The mineral mixture supplied 3 grams of $CaCO_3$ and 12 grams of NaCl per lamb.

TABLE 2

Chemical Composition of the Basal Rations Fed Lambs in the Urea and Uramite Metabolism Study

Basal Rations	Percentage Composition of Dry Matter[1]						
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.	Ash	N
High Hull	94.87	7.20	1.02	33.85	52.80	5.13	1.15
Medium Hull	95.33	6.80	1.88	21.29	65.36	4.67	1.09
Low Hull	96.02	6.42	2.19	11.74	75.67	3.98	1.03
Medium Hay	93.88	6.47	2.52	17.86	67.03	6.12	1.03

[1] The addition of either 9.0 grams of "262" or 9.75 grams of uramite increased the crude protein of the high, medium and low hull rations to 10.55, 10.15 and 9.74 per cent respectively, and the medium hay ration to 9.86 per cent.

TABLE 3

Average Daily Nitrogen Balance and Biological Value Data for Lambs in the Urea and Uramite Metabolism Study

Ration	Trials	Intake		Excretion		N Balance	True Digested N	Absorbed N Utilized[1]	N Retained		Biological Value
		Dry Matter	N	Fecal N	Urinary N				% of Intake	% of Apparent Digested	
High Hull	no.	gm.	gm.	gm.	gm.	gm.	gm.	gm.			%
Basal	3	644	7.43	5.91	2.06	-0.54	5.06				
Basal + Urea[2]	4	655	10.78	6.38	4.72	-0.32	8.01				
Basal + Uramite[3]	4	656	10.78	8.19	2.68	-0.09	6.24				
Medium Hull											
Basal	4	644	7.02	5.23	1.53	+0.26	5.36	4.83	3.7	14.5	
Basal + Urea	4	651	10.40	5.68	4.17	+0.55	8.33	5.15	5.3	11.7	62
Basal + Uramite	4	652	10.40	7.51	2.33	+0.56	6.51	5.16	5.4	19.4	79
Low Hull											
Basal	8	658	6.78	4.06	1.50	+1.23	6.37	5.87	18.1	45.2	
Basal + Urea	4	667	10.55	4.26	3.99	+2.31	9.99	6.99	21.9	36.7	70
Basal + Uramite	4	668	10.55	5.92	2.17	+2.46	8.34	7.19	23.3	53.1	86
Medium Hay											
Basal	2	652	6.74	3.66	1.60	+1.48	6.50	6.16	21.9	48.0	
Basal + Urea	2	661	10.51	4.00	3.88	+2.63	10.17	7.34	25.0	40.4	72

1 Absorbed nitrogen utilized equals nitrogen retained plus metabolic fecal nitrogen plus endogenous urinary nitrogen.

2 The urea fed was in the form of a commercial product ("262") which contained 42 per cent nitrogen.

3 The uramite compound contained approximately 38.75 per cent nitrogen, with 63.3 per cent of the nitrogen in an insoluble form.

TABLE 4

Average Apparent Coefficients of Digestion of the Basal and Urea Rations for the Urea and Uramite Metabolism Study

Ration	Trials	Apparent Percentage Digestibility of					
		Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
	no.						
High Hull							
Basal	3	46.7	43.3	20.5	77.8	40.7	48.4
Basal + Urea	4	52.3	51.5	41.0	79.4	44.4	59.7
Medium Hull							
Basal	4	56.0	55.8	25.6	94.5	34.9	64.6
Basal + Urea	4	63.1	63.2	45.4	76.0	36.0	75.4
Low Hull							
Basal	8	67.8	67.7	40.1	78.7	13.7	78.1
Basal + Urea	4	73.4	73.5	59.6	83.9	25.4	78.2
Medium Hay							
Basal	2	59.5	57.1	45.6	63.1	43.9	66.4
Basal + Urea	2	65.7	64.2	61.9	61.3	53.5	72.7

TABLE 5

Calculated Recovery of Supplemental Nitrogen Added as Urea and Uramite to the Basal Rations

Rations Compared	Ingested Supplemental N			Absorbed Supplemental N	Insoluble Supplemental N
	In Urine	In Feces	Total	In Urine	In Feces
	%	%	%	%	%
Urea Rations					
High Hull	71	12	83	81	
Medium Hull	70	12	82	80	
Low Hull	66	5	71	70	
Average	69	10	79	77	
Uramite Rations					
High Hull	16	60	76	42	95
Medium Hull	21	60	81	54	95
Low Hull	18	49	67	35	78
Average	18	56	75	44	89

grams, as compared to +0.26 grams obtained with the medium-hull ration. Also, the higher net energy value of the basal medium- and low-hull rations probably exerted a sparing effect on protein catabolism.

The results given in Table 3 indicate that the addition of urea and uramite to the high-hull ration containing 84 per cent cottonseed hulls, only slightly improved nitrogen retention. Nitrogen retention was increased by the addition of either urea or uramite to the medium- and low-hull basal rations. The average daily nitrogen balance obtained for the basal low-hull ration, +1.23 grams, was increased to +2.31 and +2.46 grams by the addition of urea and uramite, respectively. This increase was highly significant (P = .01). Nitrogen retention values expressed as per cent of intake, or per cent of that apparently digested, give further indications of a more efficient utilization of urea and uramite at the low level of roughage fed. Biological values for the nitrogen of the urea and uramite rations were greatest at the low-hull level.

These results are in general agreement with investigations carried out in another manner. Artificial rumen studies by Burroughs and associates (1951) and by Pearson and Smith (1943) have shown that a source of readily available carbohydrate is necessary for efficient urea utilization when cellulose is the major source of carbohydrate. The early work of Mills _et_. _al_. (1942) demonstrated that the protein content of rumen ingesta is not increased by the addition of urea when the basal ration contains only low quality roughage (timothy hay). When a small amount of starch is added to such a ration, the protein content of the ingesta increases rapidly after feeding, indicating that protein synthesis is taking place.

The addition of urea to the medium-hay ration increased average nitrogen retention from +1.48 to +2.63 grams daily in two trials. A biological value of 72 was obtained for the nitrogen of the medium-hay ration supplemented with urea as compared to 62 for the medium-hull ration so supplemented. These results suggest that prairie hay provided more favorable conditions for urea utilization than did equal amounts of cottonseed hulls as the roughage. Possibly this was due to the higher digestibility of the crude fiber fraction of prairie hay.

The average apparent digestion coefficients for the basal and urea supplemented rations are given in Table 4, with data for individual lambs in Table 28, appendix. The addition of urea to the basal rations consistently increased the average digestibility of all ration components with the exception of ether extract. The digestibility of organic matter was significantly increased ($P = .05$) in the high- and medium-hull rations, while this increase was highly significant ($P = .01$) in the low-hull ration. The digestibility of crude fiber was also significantly increased in the low-hull ration. This increase in the apparent digestibility of the ration upon the addition of urea is in agreement with the results of Briggs and associates (1948) and would suggest a more active rumen flora when urea is present. Further, it is of interest to note that the progressive decrease in crude fiber digestibility on the basal ration, when corn and starch replaced cottonseed hulls at the medium and low levels of roughage intake, was partially overcome by the addition of urea.

As a basis for further comparisons of urea and uramite, Table 5 has been prepared. The calculated recovery from feces and urine of supplemental urea and uramite nitrogen when each was added to the high-, medium- and low-hull basal rations has been derived from data given in Table 3. These values indicate that urea nitrogen added to the basal rations was largely excreted in the urine, averaging 69 per cent. Recovery of urea nitrogen in the feces was small, but consistent. This slight increase in fecal nitrogen when urea is added to rations has been taken by some workers as evidence of the conversion of urea nitrogen to bacterial protein, the latter being incompletely digested (Johnson et. al., 1942). The absorbed urea nitrogen recovered in the urine became progressively less as cottonseed hulls were replaced by concentrates in the rations. Whether or not this excretion of absorbed nitrogen could have been decreased by further additions of energy to the ration was not determined, but the trend suggests such a possibility.

In contrast to urea, the nitrogen of uramite was largely excreted in the feces, averaging 56 per cent of the amount fed in the different rations. Only 18 per cent was recovered in the urine. Further, an average of only 44 per cent of the uramite nitrogen absorbed was excreted in the urine, as compared to an average of 77 per cent for urea. An average of 89 per cent of the so-called "insoluble" nitrogen of uramite, which constituted 63.3 per cent of the total nitrogen was recovered in the feces. Apparently neither the rumen bacteria nor the digestive system of the lamb were effective in acting on this insoluble urea complex and releasing the nitrogen. It is of interest to note, however, that considerably more of it was broken down on the low-hull ration than on the high- and medium-hull rations.

From the relatively low percentage of supplemental nitrogen excreted, it would appear that both urea and uramite were efficiently utilized in a low roughage ration. In fact, the biological values obtained for the nitrogen of the urea rations compare favorably with those published by Johnson and associates (1942) who fed somewhat similar rations to lambs.

The fact that uramite, with only 37 per cent of its nitrogen in a form available for protein synthesis, promoted essentially the same nitrogen ballance as urea when fed at equivalent levels, would suggest that under the conditions of this study urea was fed in excess of the amount necessary to obtain the same nitrogen retention.

Experiment B   The Metabolism Study on the Efficiency of Urea Utilization

In the metabolism trials undertaken to study the level of urea most efficiently utilized when added to a low protein ration, the efficiency of equivalent amounts of cottonseed meal nitrogen was also observed. In this study, a total of 24 nitrogen balance trials were completed with lambs on six different rations.

The rations fed are shown in Table 6, with the average chemical composition of the rations given in Table 7. The basal ration contained 7.07 per cent crude protein on a dry matter basis, to which sufficient urea was added to raise the crude protein content to 8.45, 10.13 and 12.32 per cent; these rations were designated a, b, c and d, respectively. Two additional rations were fed in which cottonseed meal was added to the basal ration at the expense of starch and sugar to raise the crude protein level to 8.39 and 12.20 per cent. These rations were designated e and f, respectively.

The average daily nitrogen balance and biological value data for lambs fed the six rations are given in Table 8, with individual data for lambs in Table 29, appendix.

A nitrogen retention of +0.56 grams per lamb daily was obtained with the basal ration. This was increased to +1.81, +2.62, and +2,29 grams by the addition of 3.33, 7.48 and 13.05 grams of urea, respectively. This increase in nitrogen retention resulting from the addition of increasing amounts of urea to the basal ration was highly significant (P = .01). The increase in nitrogen retention at the two high levels of supplementation (rations c and d) as compared to the low level (ration b) was significant (P = .05).

There was no significant difference in nitrogen retention between rations c and d. Thus a point was apparently reached where, perhaps under the conditions

TABLE 6

Daily Allowance in Grams for Rations Fed Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ingredient[1]	Ration Designation					
	a	b	c	d	e	f
Cottonseed Hulls	262	262	262	262	262	262
Cottonseed Meal	46	46	46	46	68	132
Ground Shelled Corn	196	196	196	196	196	196
Starch	100	100	100	100	88	55
Sugar	72	72	72	72	62	36
Corn Oil	7	7	7	7	7	2
Minerals[2]	17	17	17	17	17	17
Urea[3]		3.33	7.48	13.05		

[1] In addition, each lamb received 1 ml. of fortified codliver oil daily.

[2] Mineral mixture supplied 8 grams bone meal, 7 grams NaCl, 1.4 grams Na_2SO_4 and 0.35 grams of a trace mineral mixture which supplied the elements Fe, Co, K, I, Mn and Cu in estimated required amounts.

[3] The urea fed was in the form of a commercial ("262") feeding compound which contained 42% nitrogen.

TABLE 7

Composition of the Rations Fed Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ration	Percentage Composition of Dry Matter						
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.	Ash	N
a. Basal	95.76	7.07	2.92	18.96	66.81	4.24	1.13
b. Urea	95.79	8.45	3.21	19.05	65.08	4.21	1.35
c. Urea	95.66	10.13	3.09	18.78	63.66	4.34	1.62
d. Urea	96.35	12.32	3.03	18.62	62.38	3.65	1.97
e. C. S. Meal	95.62	8.39	3.46	19.41	64.36	4.38	1.34
f. C. S. Meal	95.15	12.20	3.26	20.32	59.37	4.85	1.95

TABLE 8

Average Daily Nitrogen Balance and Biological Value Data of Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ration[1]	Intake: Dry Matter	Intake: N	Excretion: Fecal N	Excretion: Urinary N	N Balance	True Digested N	Absorbed N Utilized	N Retained: % of Intake	N Retained: % of Apparent Digested	Biological Value	Supplemental N Utilized[2]
	gm.	gm.	gm.	gm.	gm.	gm.	gm.			%	%
a. Basal	624	7.06	5.03	1.47	+0.56	5.49	4.94	7.9	27.6		
b. Urea	627	8.49	4.88	1.80	+1.81	7.09	6.20	21.3	50.1	87	89
c. Urea	631	10.22	5.04	2.56	+2.62	8.68	7.10	25.6	50.6	82	66
d. Urea	636	12.54	5.03	5.22	+2.29	11.04	6.78	18.3	30.5	61	32
e. C.S. Meal	631	8.48	4.82	1.61	+2.05	7.16	6.57	24.1	56.0	92	100
f. C.S. Meal	630	12.29	5.21	4.17	+2.91	10.58	7.43	23.7	41.1	70	43

[1] A total of 4 trials were completed with each ration.

[2] Supplemental nitrogen utilized was computed as:

$$\frac{\text{N retained on supplemented ration} - \text{N retained on basal ration}}{\text{Supplemental N added to basal ration}} \times 100$$

TABLE 9

Average Apparent Coefficients of Digestion for Rations Fed Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ration	Apparent Percentage of Digestibility: Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
a. Basal	57.7	58.0	28.8	90.8	24.9	69.1
b. Urea	66.6	67.3	43.2	92.7	42.5	76.6
c. Urea	70.8	71.5	50.7	90.7	49.4	81.9
d. Urea	72.0	72.8	59.9	89.9	51.4	81.4
e. C.S. Meal	65.4	66.0	43.1	92.9	39.9	75.4
f. C.S. Meal	71.2	72.0	57.6	92.1	54.5	79.8

imposed by the rations fed, an increase in the amount of urea added to the basal ration did not result in a further increase in nitrogen retention. Biological values obtained for the nitrogen of the rations were lowest on ration d, the highest level of urea supplementation.

The efficiency of utilization of the urea nitrogen steadily decreased as the amount added to the basal ration increased; supplemental nitrogen utilized was 89, 66 and 32 per cent as the level of urea added was increased in rations b, c and d, respectively. Johnson et. al. (1942) noted that the nitrogen retention of lambs could not be further increased by the addition of urea above a crude protein level of about 12 per cent, a fact which did not apply to soybean meal protein. Harris and Mitchell (1941b) observed a similar effect when urea was added to rations exceeding a crude protein level of 11 per cent. Undoubtedly the maximum level of efficient urea utilization varies according to the character of the ration. Further, the possibility exists that the level for maximum efficiency could be raised by further additions of readily available carbohydrate, although this may not always be practical or desirable.

With cottonseed meal as the source of supplemental nitrogen, crude protein levels of 8.39 and 12.20 per cent gave nitrogen retention values of +2.05 and +2.91 grams per lamb daily, which were somewhat higher than those obtained with urea rations at equivalent crude protein levels. In addition, the nitrogen retained as per cent of intake and the biological values were higher for the cottonseed meal rations than for comparable urea rations. The efficiency of utilization of cottonseed meal approached a level of 100 per cent with ration e and decreased to 45 per cent with ration f. The results suggest that even with feed proteins, such as cottonseed meal, a level is reached above which further increases of supplemental nitrogen are less efficiently utilized. However, it would appear that this level is less critical for the nitrogen of of protein than for that of urea.

The average apparent coefficients of digestion for the rations fed are shown in Table 9, with data for individual lambs in Table 30, appendix. The addition of either urea or cottonseed meal consistently increased the digestibility of all ration nutrients with the exception of ether extract. This increase was highly significant for the organic matter and crude fiber of the urea supplemented rations. Further, there was a significant increase in the digestibility of organic matter between the lowest level of urea supplementation (ration b) and the higher levels (rations c and d). There was no significant difference in the digestibility of ration nutrients at the two high urea levels (rations c and d). The digestion of organic matter was significantly increased in ration f as compared to ration e.

This increase in the digestibility of the ration resulting from the addition of urea is in agreement with the results of Experiment A. Since a like increase was noted with cottonseed meal, it appears that this effect is closely associated with increased nitrogen intake. The results support the concept of Burroughs and associates (1951a) who have advanced the theory that the requirements of the rumen microorganisms are relatively simple and that ammonia, rather than the complex protein molecule, is needed for the digestion of cellulose at an increased rate.

<u>Experiment C</u> The Value of Methionine in Rations Containing Urea

The rations fed in this study are shown in Table 10, and their average chemical composition is given in Table 11. The basal rations to which urea and methionine were added were similar in percentage composition to those fed during Experiment B, and contained about 7 per cent crude protein. In four rations, urea was added to raise the crude protein level to approximately

10 per cent, with urea supplying nearly 30 per cent of the total nitrogen. A total of 32 metabolism trials were completed.

Rations m and n were the same in percentage composition as the basal ration plus 7.48 grams of urea fed during the previous experiment. In addition, ration n contained 1.6 grams of methionine. The nitrogen balances obtained with these rations were somewhat less than had been observed in Experiment B; consequently, in subsequent rations, the daily feed allowance was increased from 700 to over 900 grams per day. Rations o and p contained essentially the same percentage composition as rations m and n, respectively. Rations q and r represent the low protein basal ration, with an average of 4.13 grams of methionine added to ration r.

In the supplemented rations (p and r) three different levels of methionine were fed. The amounts fed by trials are shown in footnote 4, Table 10. Since the response of the lambs appeared unrelated to the level of methionine added, the data obtained with different levels on the same ration have been grouped together.

Table 12 gives the average daily nitrogen balance and biological value data of lambs fed the various rations, with data for individual lambs in Table 31, appendix. The average digestion coefficients obtained are shown in Table 13, with data for individual lambs in Table 32, appendix.

The results indicate that lambs on the urea rations supplemented with methionine (n and p) retained slightly more nitrogen than lambs on these same rations without methionine (m and o). However, this advantage was not statistically significant. Nitrogen retentions, expressed as per cent of intake, were 13.3 and 18.3 per cent for urea rations m and o, and 16.4 and 20.9 for methionine supplemented rations n and p, respectively. The biological values were essentially unchanged by additions of methionine to these

TABLE 10

Average Daily Allowance in Grams for Rations Fed in the Urea and Methionine Metabolism Study

	Ration Designation and Description					
	m	n	o	p	q	r
Ingredient[1]	Urea	Urea +Meth.	Urea	Urea + Meth.	Low Protein	Low Protein + Meth.
Cottonseed Hulls	262	262	352	352	371	371
Cottonseed Meal	46	46	62	62	65	65
Ground Shelled Corn	196	196	262	262	277	277
Starch	100	100	134	132	141	141
Sugar	72	72	97	97	102	102
Corn Oil	7	7	9	9	10	10
Minerals[2]	17	17	23	23	24	24
Urea[3]	7.48	7.48	10.03	10.03		
Methionine		1.60		2.33[4]		4.13[4]

[1] In addition, each lamb received 1 ml. of fortified codliver oil daily.

[2] Minerals supplied 8 gm. bone meal, 7 gm. NaCl, 1.4 gm. Na_2SO_4 and 0.35 gm. trace minerals.

[3] The urea fed was a commercial product ("262") which contained 42% nitrogen.

[4] DL-methionine was added to daily rations fed as follows: Ration p, 2.0 gm. for 4 trials and 3.0 gm. for 2 trials; Ration r, 3.0 gm. for 5 trials and 6.0 gm. for 3 trials. Amounts given in table represent average for the ration.

TABLE 11

Average Chemical Composition of Rations Fed in the Urea Methionine Metabolism Study

Ration	Percentage Composition of Dry Matter						
	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.	Ash	N
m Urea	95.79	10.06	3.09	18.78	63.87	4.21	1.61
n Urea + Methionine	95.79	10.08	3.09	18.78	63.86	4.21	1.61
O Urea	95.80	10.22	3.08	18.80	63.69	4.20	1.64
p Urea + Methionine	95.79	10.23	3.09	18.78	63.69	4.20	1.64
q Low Protein	95.77	7.16	2.92	18.95	66.73	4.23	1.14
r Low Protein + Meth.	95.76	7.42	2.92	18.88	66.53	4.24	1.19

TABLE 12

Average Daily Nitrogen Balance and Biological Value Data for the Urea and Methionine Metabolism Study

Ration	Trials	Intake		Excretion		N Balance	True Digested N	Absorbed N Utilized	N Retained		Biological Value
		Dry Matter	N	Fecal N	Urinary N				% of Intake	% of Apparent Digested	
	no.	gm.	gm.	gm.	gm.	gm.	gm.	gm.			%
m Urea	2	631	10.15	4.01	4.79	+1.35	9.63	5.96	13.3	22.0	62
n Urea + Methionine	2	633	10.19	3.90	4.62	+1.67	9.80	6.29	16.4	26.6	64
o Urea	6	846	13.84	6.67	4.64	+2.53	11.87	8.44	18.3	35.3	71
p Urea + Methionine	6	847	13.88	6.08	4.90	+2.90	12.51	8.88	20.9	37.2	71
q Low Protein	8	883	10.10	6.58	2.13	+1.39	8.42	7.64	13.8	39.4	91
r Low Protein + Meth.	8	887	10.52	6.59	2.48	+1.45	8.85	7.72	13.8	36.9	87

TABLE 13

Average Apparent Coefficients of Digestion for Rations Fed in the Urea and Methionine Metabolism Study

Ration	Percentage Digestibility of					
	Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
m Urea	73.5	74.1	60.5	93.2	54.1	81.3
n Urea + Methionine	75.3	75.9	61.7	93.6	58.6	82.3
o Urea	67.9	68.3	51.6	90.8	40.8	77.9
p Urea + Methionine	70.8	71.3	56.2	89.1	47.7	79.8
q Low Protein	61.6	61.8	34.8	90.6	33.7	71.4
r Low Protein + Methionine	60.2	60.2	37.2	91.3	30.2	70.0

rations. The slight increase in nitrogen retention on the methionine rations (n and p) was associated with an increase in the digestibility of all ration nutrients, with the exception of ether extract. The increase in digestibility for organic matter and crude fiber was not statistically significant. These data suggest that a more active rumen microflora was present when methionine was added to the urea rations.

On the low protein ration (q) and this ration supplemented with methionine (r), average nitrogen retention, expressed as per cent of intake, was the same. The digestibility of the low protein ration was not improved by the addition of methionine, in contrast to the results obtained with the urea rations.

Since a slight increase in nitrogen retention and ration digestibility was obtained when methionine was added to rations containing urea, it would appear that the presence of adequate amounts of dietary nitrogen may be necessary if methionine is to exert a beneficial effect. In this study, methionine was fed at levels of from 0.24 to 0.60 per cent of the total ration, which was somewhat higher than fed by Lofgreen and associates (1947) who added methionine at the rate of 0.2 per cent of the total ration.

With the exception of the two trials completed with ration n, average urinary nitrogen excretion was slightly increased when methionine was added to the ration. Allison et. al. (1948) have shown in nitrogen balance studies with dogs that methionine decreases urinary nitrogen excretion. Thus it would appear that any beneficial action of methionine in rations for lambs may be due to its effect on bacterial protein synthesis.

In the methionine experiments of Loosli and Harris (1945), and later in those of Lofgreen and associates (1947), some improvement in nitrogen retention was obtained when sodium sulfate was added to the urea rations. Garrigus *et. al.* (1950) observed an improvement in the weight gains and wool production of lambs when inorganic sulfur was added to methionine-deficient rations. The performance of these lambs was not significantly different from those fed equivalent amounts of methionine. In the metabolism studies reported here, the daily rations contained 1.4 grams of sodium sulfate as part of the mineral mixture, in addition to the sulfur present in the feeds used. However, Willman, Morrison and Klosterman (1946) found that the addition of sodium sulfate to the rations of fattening lambs in which urea was used as the nitrogen supplement, did not improve weight gains.

Although Loosli and associates (1949) have shown that methionine is synthesized in the rumen of lambs fed rations in which urea furnished nearly all of the nitrogen, the work of Johanson, Moir and Underwood (1949) indicates that the rumen bacteria of sheep have a high requirement for this amino acid. They found that the methionine content of the bacterial protein of sheep was high as compared to common proteins, and was about equal to that found in proteins such as casein and muscle.

In view of these results, it would seem that further research is necessary in order to establish the importance of inorganic sulfur and methionine as it affects urea utilization by ruminants.

Summary of the Nitrogen Balance and Digestion Studies with Lambs

Nitrogen balance and digestion trials were conducted with lambs to study (a) the relative value of urea and uramite as nitrogen supplements when added to low-protein rations which varied in percentage composition of low-quality roughage, (b) the efficiency of urea utilization, as compared to cottonseed meal, when increasing amounts were added to a low-protein ration, (c) the value of methionine when added to a low-protein ration, and to similar rations supplemented with urea, and (d) the effect of urea on the digestibility of the ration.

The results obtained indicate that the level of low-quality roughage in the basal ration markedly affects the degree of urea utilization; urea being most efficiently utilized when added to rations low in poor quality roughage (cottonseed hulls) and high in readily available carbodydrate. A new product, uramite, was found to be an impractical supplement since it contains a high percentage of indigestible nitrogen.

Urea was more efficiently utilized when added to a basal ration in amounts sufficient to raise the crude protein level from 7.07 to 8.45 and 10.13 per cent, than when the crude protein level was increased to 12.32 per cent by further additions of urea. Maximum nitrogen retention was obtained at the 10.13 per cent crude protein level. A similar effect was observed with cottonseed meal, although this source of nitrogen was more efficiently utilized than urea at both the low and high levels of supplementation.

The addition of from 0.24 to 0.31 per cent DL-methionine to urea rations which were not deficient in sulfur, slightly improved nitrogen retention and ration digestibility. Essentially no improvement was noted when methionine was added to a low-protein ration.

In these studies, the addition of urea to low-protein rations consistently increased the digestibility of all ration nutrients, with the exception of ether extract. A similar increase in digestibility was obtained when cottonseed meal was added in nitrogen equivalent amounts.

PART II

THE UTILIZATION OF UREA BY EWES DURING GESTATION AND LACTATION

Metabolism studies have shown that sheep can use urea as a source of nitrogen. However, metabolism trials are of short duration and subject to many errors which may be partially corrected by longer experiments. It is recognized that the protein requirements of the ewe are most critical shortly before lambing and during early lactation. It seemed desirable, therefore, to study the utilization of urea by ewes during gestation and lactation in comparison to the utilization of a common protein supplement such as cottonseed meal. The relative value of the two supplements was measured by the gain or loss in body weight of the ewe during gestation and lactation, the weight of the lamb at 42 days, and the grease weight of the fleece.

Two experiments were conducted with fine-wool ewes during the 1949-50 and 1950-51 winter periods; these are designated as Trials I and II, respectively.

Trial I. The 1949-50 Study

Experimental

Thirty, solid-mouthed ewes of New Mexico origin were purchased in November, 1949. They were drenched with phenothiazine and exposed to a purebred Hampshire ram. They were started on the experimental rations December 10, 1949, after it was apparent that all ewes were with lamb. They were allotted at random into three groups of 10 ewes each on the basis of body weight. Lot 1 was designated the low-protein basal group, Lot 2 the low-protein plus urea, and Lot 3 the cottonseed meal positive control group.

The experiment was conducted at the experimental barn. Ewes of all lots had access to the same exercise lot during the day. They were sorted into their respective lots at the time of the evening feed and fed the prairie hay part of the ration. The concentrate portion of the ration was fed once daily in individual stanchioned stalls. The concentrate mixture for each lot was prepared in large quantities sufficient for several weeks and weighed into individual containers. The daily concentrate allowance was measured out in a small graduated cup. Urea was thoroughly mixed in the feed mixture prepared for Lot 2.

The ewes of Lot 1 were fed a basal ration of corn, starch and prairie hay which was estimated to be adequate in energy, but low in protein. Lot 2 was fed a similar ration plus urea in amounts sufficient to meet the National Research Council recommendations for digestible crude protein. Lot 3 ewes were fed a ration of corn, cottonseed meal and prairie hay which was equal in nitrogen content to Lot 2. A mixture of two parts of salt and one part of bone meal, with added cobalt, was available to the ewes of all lots.

The rations fed the ewes of all lots were increased during the course of the experiment in an attempt to compensate for the increasing nutrient requirements of the ewes as the experiment progressed. Three increases were made and these are designated as rations A, B, and C for each lot. Ration A was fed from the start of the experiment until approximately 6 weeks before lambing. Ration B was fed during the last 6 weeks of gestation and the first 10 days of lactation. Ration C was fed for the remainder of the lactation phase. The ewes were fed twice daily while receiving ration C, one-half the daily allowance at each feeding.

The ewes of all lots were fed 2.5 pounds of prairie hay per head daily at the start of the experiment. It soon became apparent that ewes of Lots 1 and 2 would not consume this amount, and the hay offered to all lots was reduced to 2.0 pounds per head daily. Refused hay was weighed back once daily and the amount deducted from the daily allowance to determine the hay intake.

After the ewes had been on experiment for 36 days (January 15, 1950), the weight gains, general condition and appetites of the ewes of Lots 1 and 2 indicated that the rations fed these lots were inadequate. A small amount of cottonseed meal (0.05 pounds per head daily) was added to the ration of Lots 1 and 2 at this time. Urea in the ration of Lot 2 ewes was reduced to maintain the same total protein intake as Lot 3. It was also necessary to substitute cane sugar for one-half the starch in rations for ewes of Lot 2 in order to improve the palatability of the urea rations. Some difficulty was encountered in obtaining complete consumption of the concentrate mixture fed ewes of Lots 1 and 2 as the experiment progressed.

The ewes were weighed at 14-day intervals during gestation, as soon as possible after lambing, and at the end of 42 days of lactation. The lambs were weighed at birth, and at 5, 10, 21, and 42 days of age. After lambing, the ewes and their lambs were placed in small individual pens for five days. The lambs were docked at 3 days of age and ram lambs were castrated at two weeks of age. The experimental treatments were terminated as the ewes completed the 42nd day of lactation. The ewes were shorn at the completion of the experiment.

Blood samples of the ewes were taken before the start of the experiment, and at 4-week intervals. Blood samples were taken in the evening, about 3 hours after feeding the concentrate portion of the ration, with the exception of two bleedings (February 15 and March 4) as indicated in footnotes 2 and 3, Table 17. Urea in the blood and colostrum was determined by the colorimetric method of Archibald (1947). The data were subjected to an analysis of variance (Snedecor, 1946).

Results and Discussion

It developed that twelve ewes were pregnant at the time they were purchased for the experiment. The lambs from these ewes were of fine-wool breeding, and their performance has been listed separately in the data presented.

The chemical composition of the feeds used are shown in Table 14, and the average daily rations in Table 15. The average body weights of the ewes during gestation and lactation, fleece weights, and lamb production records are shown in Table 16, with individual data for the ewes in Table 33, appendix.

Considerable death loss occurred among ewes fed the low protein and urea rations. These ewes, four in Lot 1 and two in Lot 2, exhibited symptoms of "pregnancy disease," becoming progressively weaker and emaciated, with a loss of appetite and inability to rise or stand during the latter stages. Various treatments were given these ewes, including molasses, casein and yeast in milk drenches, and the administration of 5 grams of choline chloride by capsule. These treatments were without success. Three of the six ewes which were lost were carrying twin fetuses. One ewe in Lot 2 aborted shortly before term and recovered. One ewe in Lot 3 also aborted, but the condition of the ewe and her weight gains during pregnancy indicated that probably this was not due to the ration. Hilston et. al. (1951) observed a higher death loss among pregnant ewes fed a basal ration of native hay, molasses and corn, than among ewes fed the same ration plus urea. These results suggest that during a critical period of low-protein intake, urea may exert a beneficial effect through the formation of bacterial protein as well as by increasing the utilization of other nutrients in the ration (as shown in Part I).

Chemical Composition of Feeds Used in Trial I

Feeds	Per cent Dry Matter	Percentage Composition of Dry Matter				
		Ash	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
Ground Shelled Corn	89.69	1.43	9.60	4.86	1.81	82.30
Cottonseed Meal	92.81	5.34	42.69	7.24	11.36	33.37
Prairie Hay	94.07	7.29	4.82	2.27	33.45	52.17

TABLE 15

Average Daily Rations Fed Ewes During Trial I[1]

Ingredient	Ration A			Ration B			Ration C		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
Ground Shelled Corn . . lbs.	0.22	0.22	0.22	0.40	0.40	0.40	0.67	0.67	0.67
Cottonseed Meal . . . . lbs.	0.03[2]	0.03[2]	0.27	0.10	0.10	0.35	0.17	0.17	0.50
Starch . . . . lbs.	0.25	0.13		0.25	0.13		0.40	0.20	0.03
Cane Sugar . . . . . . lbs.		0.12			0.12			0.20	
Prairie Hay . . . . . . lbs.	1.85	1.89	2.10	1.64	1.71	2.00	1.64	1.71	2.00
Urea[3] . . . . gms.		14.80			17.00			22.60	
Crude Protein Intake (lbs./day)	0.11	0.20	0.21	0.15	0.25	0.26	0.20	0.33	0.35

[1] Ration A was fed from the start of the experiment, 12-10-49, until approximately six weeks before lambing, 2-17-50. Ration B was fed from 2-17-50 to 10 days after lambing, and ration C was fed during the 10th to the 42nd days of lactation.

[2] Cottonseed meal (0.05 lbs. per ewe) was added to the daily rations of Lots 1 and 2 on January 15.

[3] The urea fed was a commercial product ("262") which contained 42 per cent nitrogen.

TABLE 16

Summary of Data on Average Weight Gains, Fleece Weights, and Lamb Production Records of Ewes During Trial I

	Lot 1 Basal	Lot 2 Basal + Urea	Lot 3 Cottonseed Meal
Number of ewes per lot, start of experiment	10	10	10
Number lost during experiment	4	2	0
Gestation Phase			
Average ewe weight (lbs.)			
Initial 12/10/49	105	107	108
Weight after lambing	91	94	108
Gain or loss during gestation	-14	-13	0
Average lambing date	3/28	3/18	3/25
Lactation Phase			
Average ewe weight (lbs.)[1]			
First day of lactation	89	96	111
42nd day of lactation	83	95	100
Loss during lactation	-6	-1	-11
Average fleece weight (lbs., grease basis)[2]	8.7	9.5	10.2
Lamb Production Record			
Total number of lambs born	10	11	12
Number raised to 42 days	5	7	11
Fine wool lambs			
Singles: Number raised	2	3	1
Ave. birth weight (lbs.)	7.3	8.4	10.8
Ave. 42-day weight (lbs.)	18.6	19.6	36.0
Twins: Number raised		2	4
Ave. birth weight (lbs.)		6.4	6.9
Ave. 42-day weight (lbs.)		17.5	19.2
Crossbred lambs			
Singles: Number raised	3	2	6
Ave. birth weight (lbs.)	9.4	8.0	10.0
Ave. 42-day weight (lbs.)	19.0	23.0	27.2
Ave. gain, birth to 42 days (lbs.)	9.6	15.0	17.2

[1] Pertains only to ewes which raised lambs: five in Lot 1, six in Lot 2, and nine in Lot 3.

[2] Average of six ewes in Lot 1, eight ewes in Lot 2, and ten ewes in Lot 3.

TABLE 17

Average Blood and Colostrum Urea Levels of Ewes During Trial I
(mg. per 100 ml.)[1]

	Initial Bleeding, Nov. 22	Blood Samples								Colostrum
		Jan. 14	Feb. 14	Feb. 15[2]	March 3	March 4[3]	At Lambing	May 13	Average	
Lot 1	22.1	4.9	10.6	7.8	8.2	7.5	8.5	8.3	7.9	7.6
Lot 2	22.7	26.1	37.9	34.4	33.5	23.4	27.0	29.7	30.5	19.4
Lot 3	18.6	12.9	20.9	18.2	16.9	14.9	20.5	18.1	17.4	16.8

[1] Samples at lambing taken only from ewes which lambed normally. Samples taken May 13 were from ewes which had nursed lambs.

[2] Blood samples taken approximately 12 hours after February 14th bleeding.

[3] Blood samples taken approximately 20 hours after May 3rd bleeding.

The average weight loss of ewes during gestation, as shown in Table 16, was -14, -13 and 0 pounds for Lots 1, 2, and 3, respectively. Differences in loss of body weight between ewes of Lots 2 and 3 were highly significant (P = .01). During the lactation phase, the ewes of Lot 3 lost more weight than ewes of Lots 1 and 2, although this was not significant and may have been due to the superior condition of Lot 3 ewes at the start of lactation. At the completion of the experimental treatments (42nd day of lactation) the average weight of the ewes in Lots 1, 2, and 3 was 83, 95, and 100 pounds, respectively.

With the exception of a greater weight loss during lactation, the performance of ewes of Lot 3 was consistently superior to that of Lot 2 throughout the experiment. Lot 3 ewes maintained their body weight during gestation, produced heavier lambs at 42 days, and sheared heavier fleeces than ewes of Lot 2. Since the energy content of their rations was nearly equal, it is probable that the differences in performance were due to the inability of the ewes of Lot 2 to utilize the crude protein (nitrogen) of their rations as efficiently as the ewes of Lot 3. Rasmussen (1951) found that ewes fed brome grass hay and a protein supplement containing 10 per cent urea, gained less during 102 days of the gestation period than ewes fed equivalent amounts of soybean meal.

There is some indication that the performance of ewes fed the urea rations (Lot 2) improved during the lactation phase, as compared to ewes fed the low protein basal (Lot 1). Ewes of Lot 2 lost less weight during lactation, produced slightly heavier lambs at 42 days, and sheared heavier fleeces than ewes fed the low protein ration (Lot 1). The appetites of ewes on the urea ration were observed to improve as the experiment progressed, in contrast to ewes fed the low protein ration. Hilston and associates (1951) noted a lack of appetite among ewes fed low protein rations supplemented with urea; these rations were fed once daily. In the experiment reported here, the rations were fed twice daily, from the 10th to 42nd days of lactation. Dinning (1947) found that steers were able to store more nitrogen when fed urea pellets twice daily, than when fed twice the daily allowance on alternate days.

The blood and colostrum urea levels of the ewes are shown in Table 17. Ewes of Lot 2 had consistently higher blood urea levels than ewes of the other lots. Differences in average blood urea levels between ewes of Lots 2 and 3, throughout the experiment, were highly significant (P = .01) although the crude protein intakes of the two lots were nearly equal. The high blood urea levels of Lot 2 ewes is probably an indication of poor utilization of the nitrogen in the ration. The blood urea levels for ewes of Lot 3, fed the cottonseed meal rations, fell within the range of 8 to 20 mg. per 100 cc. of whole blood given by Dukes (1947) as normal for sheep. Ewes of Lot 1, fed the low protein rations, had lower blood urea levels throughout the experiment. Differences in blood urea levels between Lot 1 and Lots 2 and 3 were highly significant (P = .01).

Blood samples taken 12 hours after the regular bleeding time (February 15), or 20 hours after the regular time (March 4) show that a slight decrease in blood urea of the ewes occurred in all lots during the interval between feedings. However, Lot 2 ewes fed the urea rations were consistently higher in blood urea than ewes of the other lots, regardless of the time of bleeding. This would indicate that the high blood urea levels observed in samples taken at regular bleeding time (3 hours after the evening feed) were maintained during the day.

Colostrum urea levels, shown in Table 17, were significantly higher for ewes of Lots 2 and 3 than for ewes of Lot 1 (P = .05). There was no statistical difference in the concentration of urea in the colostrum of ewes of Lots 2 and 3. Rupel, Bohstedt and Hart (1943) were unable to show an abnormal increase in the urea nitrogen content of the milk of dairy cows fed urea at a level of 3 per cent of the concentrate mixture.

From the resultsobtained in Trial I, it seems apparent that urea, fed in amounts ranging from 15 to 23 grams per ewe daily, was not harmful to the ewe during pregnancy and lactation, or to the nursing lamb. However, the ability of ewes to utilize urea nitrogen was distinctly less than their ability to utilize the nitrogen of cottonseed meal under the conditions of this study.

Trial II. The 1950-51 Study

Experimental

The experimental procedure employed in Trial II was essentially the same as previously described for Trial I. To eliminate the possibility of a carry-over effect of the previous trial, a new group of ewes were purchased in the fall of 1950. To increase the uniformity and palatability of the concentrate mixtures, this portion of the ration was pelleted.

Thirty, fine-wool, solid-mouthed ewes of Texas origin were purchased in September, 1950. They were drenched with phenothiazine and exposed to a purebred Hampshire ram which was different than the one used in Trial I. During the breeding period, the ewes were fed a ration of 1.0 pound of oats per head daily and had access to alfalfa and prairie hay. When it was apparent that all ewes were bred, they were allotted into three groups of 10 ewes each on the basis of body weight and started on experiment November 20, 1950.

The ewes of all lots received 2.0 pounds of prairie hay per head daily throughout the experiment. From the start of the experiment until 7 days after lambing, each ewe received 1.0 pound daily of a pelleted feed mixture, and 2.0 pounds daily thereafter. During the period extending from the 7th to the 42nd days of lactation, the rations were fed twice daily, one-half the daily allowance at each feeding. As in the previous trial, the ewes were stanchioned in individual stalls to receive the concentrate portion of the ration.

The composition of the pelleted feed mixtures used, according to lots, was as follows:

Lot 1 -- Low protein pellets containing ground shelled corn, cottonseed meal, starch, molasses and dicalcium phosphate, with a total protein content of approximately 10 per cent.

Lot 2 -- Urea pellets containing the same feeds as shown for Lot 1, plus urea to raise the crude protein level to approximately 15 per cent.

Lot 3 -- Cottonseed meal pellets containing ground shelled corn, cottonseed meal and molasses, with a total protein content of approximately 15 per cent.

Starch was added to the feed mixtures for Lots 1 and 2 to make the pellets approximately equal in energy. Dicalcium phosphate was added to make the phosphorus content of the pellets fed Lots 1 and 2 approximately equal to those fed Lot 3. In addition, a mixture of two parts of salt and one of bone meal, with added trace minerals, was available to the ewes of all lots.

Ewe and lamb weights were obtained in the same manner as previously described in Trial I. In order to obtain a better measure of lamb gain per ewe, ewes with twins were given the largest lamb to raise as a single.

Blood samples were taken in the morning at periodic intervals for the determination of urea and hemoglobin levels. Blood and colostrum samples were taken as soon as possible after lambing. Hemoglobin was determined by the acid hematin method of Wong (1928).

Milk production was determined by separating the ewes from their lambs and weighing the lambs in and out four times daily for two consecutive days between the 42nd and 50th days of lactation. During this phase of the experiment, the ewes were handled in trios, with one ewe from each lot on test at the same time.

It developed that six of the original ewes were pregnant when purchased for the experiment. They were taken off experiment during the second month and are not included in the data presented. Three ewes were from Lot 1, two from Lot 2 and one from Lot 3. In addition, one ewe in Lot 1 developed udder trouble shortly after lambing and another lost her lamb at birth due to faulty presentation of the fetus; data for these ewes are not included for the lactation phase.

Results and Discussion

The chemical composition of the feeds used are shown in Table 18, with the average daily rations and crude protein intakes given in Table 19.

The average gain or loss in body weight of the ewes during the experiment, together with the average fleece weights and lamb production records, are shown in Table 20, with data for individual ewes in Table 34, appendix.

Ewes fed the low protein pellets (Lot 1) lost an average of 3 pounds of body weight during the gestation period, while ewes fed equal amounts of urea and cottonseed meal pellets (Lots 2 and 3) gained an average of 6 and 7 pounds, respectively. This difference was highly significant (P = .01).

Ewes fed the low protein pellets (Lot 1) lost more weight during lactation than ewes of the other lots, although this difference was not significant. At the completion of the experiment (42nd day of lactation) the average weights of the ewes were 98, 106, and 110 pounds for Lots 1, 2, and 3, respectively. Although ewes fed the cottonseed meal pellets (Lot 3) gained more weight during gestation and lost less weight during lactation than ewes fed the urea pellets (Lot 2), these differences were small and were not significant.

There was no significant difference in the birth weights of the lambs, although single lambs from ewes fed the low protein pellets were lighter, on the average, than single lambs from ewes fed the urea and cottonseed meal pellets. Slen and Whiting (1952) found that the birth weight of lambs was significantly affected by the protein content of the rations fed ewes during gestation. Hilston et. al. (1951) reported that lambs from ewes fed low protein rations supplemented with urea were significantly lighter at birth than lambs from ewes receiving the same amount of supplemental nitrogen in the form of soybean meal.

A total of six ewes in Lot 1, eight in Lot 2, and eight in Lot 3 completed the lactation phase of the experiment, each ewe nursing one lamb. There was little difference in the average weight of the lambs of the various lots at 5 days of age. Differences in average weight of the lambs, in favor of Lots 2 and 3, were noticeable at 10 days and thereafter. The average gains in weight from birth to 42 days were 16.1, 21.1 and 22.8 pounds for lambs of Lots 1, 2 and 3, respectively. This increase in the gain to 42 days for lambs of Lots 2 and 3, as compared to Lot 1, was statistically significant ($P = .05$). There was no significant difference in the weight gains of Lot 2 and Lot 3 lambs. Whiting and Slen (1951) have shown that the gains made by lambs from birth to 7 weeks of age are significantly correlated ($r = 0.76$) with the milk production of the ewe. Thus the increased rate of gain of lambs from ewes of Lots 2 and 3 may be taken as a measure of the milk production of the ewes, which depends on adequate supplies of protein in the ration (Whiting and Slen, 1951).

The fleece weights of ewes of Lots 2 and 3 were significantly heavier ($P = .05$) than the fleece weights of ewes of Lot 1. Some "breaks" were noted in the fleeces of ewes fed the low protein pellets, which is often indicative

TABLE 18

Chemical Composition of Feeds Used in Trial II

Lot	Feeds	Per cent Dry Matter	Percentage Composition of Dry Matter				
			Ash	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
1	Low Protein Pellets[1]	93.21	3.77	10.32	3.87	2.40	79.64
2	Urea Pellets[2]	93.12	3.21	15.08	3.98	2.09	75.63
3	Cottonseed Meal Pellets[3]	92.62	4.18	15.30	4.82	4.20	71.50
All	Prairie Hay	94.86	6.95	4.91	1.96	33.99	52.19

[1] Low protein pellets contained 70% ground shelled corn, 5% cottonseed meal, 14% starch, 10% molasses and 1% dicalcium phosphate.

[2] Urea pellets contained 68% ground shelled corn, 5% cottonseed meal, 14% starch, 10% molasses, 1% dicalcium phosphate and 2.1% urea ("262").

[3] Cottonseed meal pellets contained 70% ground shelled corn, 20% cottonseed meal and 10% molasses.

TABLE 19

Average Daily Rations Fed Ewes and Crude Protein Intakes During Trial II

	Lot 1 Low Protein Pellets	Lot 2 Urea Pellets	Lot 3 Cottonseed Meal Pellets
	lbs.	lbs.	lbs.
Gestation Phase[1]			
Pelleted Feed	1.0	1.0	1.0
Prairie Hay	2.0	2.0	2.0
Crude Protein Intake (lbs./day)	0.19	0.23	0.23
Lactation Phase[2]			
Pelleted Feed	2.0	2.0	2.0
Prairie Hay	2.0	2.0	2.0
Crude Protein Intake (lbs./day)	0.29	0.37	0.38

[1] Fed from start of experiment to 7 days after lambing.

[2] Fed from 7th to 42nd day of lactation.

TABLE 20

Summary of Average Weight Changes, Fleece Weights and Lamb Production Records of Ewes During Trial II

	Lot 1 Low Protein Pellets	Lot 2 Urea Pellets	Lot 3 Cottonseed Meal Pellets
Number of ewes per lot	7	8	9
Gestation Phase			
Average ewe weight (lbs.)			
Initial, 11-20-50	107	106	107
Weight after lambing	104	112	114
Gain or loss during gestation	-3	+6	+7
Average lambing date	3/8	3/9	3/12
Lactation Phase			
Average ewe weight (lbs.)[1]			
First day of lactation	106	112	114
42nd day of lactation	98	106	110
Loss during lactation	-8	-6	-4
Average fleece weight (lbs., grease)	7.1	8.8	9.4
Lamb Production Record			
Total number of lambs born	9	11	10
Singles	5	5	8
Twins	4	6	2
Average birth weight (lbs)			
Singles	9.8	10.7	10.3
Twins	8.0	7.2	7.6
Number of lambs raised[2]	6	8	8
Average weights (lbs.)			
At birth	9.6	9.5	9.8
At 5 days	12.9	12.8	13.1
At 10 days	14.7	15.4	16.2
At 21 days	18.5	20.9	21.8
At 42 days	25.7	30.6	32.6
Gain, birth to 42 days	16.1	21.1	22.8
Ave. daily gain to 42 days	0.38	0.50	0.54

[1] Pertains only to ewes which raised lambs.

[2] Ewes with twins given largest lamb to raise as a single. No lambs were lost of those given the ewes to raise.

of a protein deficiency. Watson et. al. (1949) observed that lambs fed low protein rations stored less nitrogen in the form of wool growth than lambs fed low proteins rations supplemented with urea.

The average daily milk production of the ewes, as determined by the difference in the weight of the lamb before and after nursing, are shown in Table 21. Although differences in milk production were not statistically significant, average daily milk production was highest for ewes of Lot 3 and lowest for ewes of Lot 1, thus tending to correspond to the average weight gains of the lambs. Whiting and Slen (1951) have shown that ewes fed 0.25 pounds of digestible crude protein per head daily during lactation, produced significantly more milk than ewes receiving 0.11 pounds of digestible crude protein.

TABLE 21

Average Daily Milk Production of Ewes Measured During Two Consecutive Days Between the 42nd and 50th Days of Lactation in Trial II (lbs.)

Lot No. and Description	Number of Ewes	Weights Recorded				
		6:30 a.m.	12.30 p.m.	5:30 p.m.	10:30 p.m.	Total
1 Low Protein Pellets	6	0.37	0.31	0.36	0.25	1.29
2 Urea Pellets	8	0.48	0.33	0.37	0.35	1.53
3 Cottonseed Meal Pellets	8	0.42	0.41	0.45	0.42	1.70

The average blood and colostrum urea levels are shown in Table 22. Blood urea levels during the experimental period were significantly higher (P = .01) for ewes of Lots 2 and 3 than for ewes of Lot 1. There was little difference in blood urea values between ewes of Lots 2 and 3. This would suggest a more efficient utilization of urea by Lot 2 ewes than occurred during Trial I. There was no significant difference among the lots in colostrum urea levels.

The average hemoglobin levels are shown in Table 23. A decrease in hemoglobin levels of the ewes of all lots occurred during the experiment. When all

TABLE 22

Average Blood and Colostrum Urea Levels of Ewes During Trial II (mg. per 100 ml.)

Lot No.	Number of Ewes	Initial Bleeding, Nov. 17	Blood Samples Compared: Dec. 12	Feb. 7	At Lambing	April 12	Average	Colostrum
1	7	26.2	3.7	10.7	10.7	3.9[1]	7.4	8.5[1]
2	8	20.8	9.0	12.2	11.9	7.6	10.2	8.5
3	9	28.5	7.8	13.2	18.7[2]	6.9[2]	11.7	10.8[2]

[1] Ewe #3082 which failed to raise a lamb not included.

[2] Ewe #3090 which lost her lamb at birth not included.

TABLE 23

Average Hemoglobin Levels of Ewes During Trial II (grams per 100 ml.)

Lot	Number of Ewes	Initial Bleeding, Nov. 17	Blood Samples Compared: Dec. 12	Feb. 7	At Lambing	April 12	Average
1	7	11.2	12.8	9.7	9.6	9.8[1]	10.5
2	8	11.1	12.5	9.7	8.9	8.7	9.9
3	9	11.2	12.2	10.8	10.3[2]	9.6[2]	10.8

[1] Ewe #3082 which failed to raise a lamb not included.

[2] Ewe #3090 which lost her lamb at birth not included.

hemoglobin values obtained during the experiment were analyzed, and differences due to time of bleeding removed statistically, the hemoglobin levels of Lot 3 ewes were significantly higher than those of Lot 2 (P = .05). Ewes fed the low protein pellets (Lot 1) had higher average hemoglobin levels than ewes fed the urea pellets. Nash (1950) and Klosterman et. al. (1950) have shown that low hemoglobin levels are associated with poor nutrition of the ewe during reproduction and lactation. In view of the similarity in the performance of ewes of Lots 2 and 3 during the experiment, differences in hemoglobin levels are difficult to explain.

In this trial, ewes fed the urea pellets (Lot 2) were consistently superior to ewes fed the low protein pellets (Lot 1) during the experiment. They closely approached, but did not equal, ewes fed cottonseed meal pellets (Lot 3) in the measures of production studied. These results show that urea nitrogen in the pellets fed Lot 2 was being utilized. In view of the metabolism trials conducted in Part I, the increased performance of ewes on the urea rations during Trial II, as compared to Trial I, may have been due either to greater amounts of readily available carbohydrate in the ration, or to the lower urea intake which may have resulted in a more efficient utilization. From the analyses of the pellets, it was estimated that the daily urea intake of Lot 2 ewes was 7.5 grams during the gestation phase, and 15 grams during the lactation phase.

Summary of the Utilization of Urea by Ewes During Gestation and Lactation

Two trials were conducted with fine-wool ewes to determine the value of urea as a source of crude protein (nitrogen) during pregnancy and lactation. Urea and cottonseed meal were compared as supplements to low protein rations and the performance of the ewes was measured by the gain or loss in body weight during pregnancy and lactation, the weight of the lamb at 42 days, and the weight of the fleece at shearing.

Results obtained in the first trial indicated that ewes fed a basal ration of corn, cottonseed meal, starch and prairie hay made unsatisfactory use of supplemental urea. Their performance was only slightly better than that of ewes fed the low protein ration. Ewes fed cottonseed meal as the source of supplemental nitrogen maintained their body weight during pregnancy, while ewes of the other lots lost considerable weight. They also produced heavier lambs at 42 days, and sheared heavier fleeces than ewes on the low protein, or urea, rations. Blood urea levels were significantly higher for ewes fed the urea ration, which may have been due to poor urea utilization.

In the second trial, the concentrate mixtures were pelleted and fed at a higher level. Urea utilization was improved and ewes fed the urea pellets did not differ significantly in performance from ewes fed the cottonseed meal pellets containing approximately the same amount of crude protein. Ewes of both lots gained more weight during pregnancy, produced lambs that gained more to 42 days and sheared heavier fleeces than ewes fed equal amounts of the low protein pellets; these differences were statistically significant. Blood and colostrum urea levels for ewes fed the urea and cottonseed meal pellets were not significantly different. Hemoglobin levels of ewes fed the urea pellets were significantly lower than those of ewes fed cottonseed meal pellets. Milk production of the ewes, while not significantly different, tended to follow the same pattern as lamb gains.

PART III

THE UTILIZATION OF UREA BY FATTENING LAMBS

Protein supplements are considered necessary when non-legume hay is the only roughage in lamb-fattening rations. Even with rations containing a legume roughage, Morrison (1949) states that the addition of a small amount of protein supplement will often improve the rate of gain, but may not always result in additional profit due to the increased feed cost. Willman, Morrison and Klosterman (1946) found that rations containing 11 per cent crude protein were superior to those containing 9 to 10 per cent for lambs weighing about 60 pounds at the start of the feeding trial. These same authors found that urea was a poor source of nitrogen as compared to linseed meal in practical rations for fattening lambs in drylot.

With these results in mind, experiments were designed to further study the value of urea in fattening rations for lambs. The trials were conducted during the summer and early fall of 1950 and 1951 and are designated Trials I and II, respectively.

In Trial I, the effect of adding urea to a corn, soybean meal and mixed hay ration in amounts sufficient to raise the crude protein content of the ration from 9.7 to 11.5 per cent was studied. In Trial II, the relative value of urea and cottonseed meal were compared when each was added to a corn, beet pulp and prairie hay ration. The possibility of enhancing urea utilization by gradually increasing the level of urea in the ration during the first 30 days of the feeding trial was further investigated.

Experimental

The lambs used were from the experimental flock and were out of ewes which had been used for nutritional studies during the previous winter. They were approximately 4 months old at the start of the feeding trials and weighed about 55 pounds. Nearly 3 months had elapsed between the completion of the previous winter experiments and the start of the summer feeding trials. During this time, the lambs were fed adequate rations and had access to spring pasture. The lambs were allotted in the feeding trials without consideration for the previous winter treatment of their dams.

The first feeding trial started July 31, 1950, and continued for 84 days. Two groups of 8 lambs each were used, with both sexes represented in each lot. Four lambs in each lot were Hampshire X fine-wool crossbreds, and the remainder were of fine-wool breeding. The lambs were sheared about a week before the start of the feeding trial and drenched with a copper sulphate-nicotine sulphate solution. The two lots were fed equal amounts of a corn, soybean meal and mixed hay ration. In addition, lambs of Lot 2 received 8 grams of urea ("262") per head daily mixed with the concentrate portion of the ration. The mixed hay consisted of alfalfa in the morning and prairie hay in the evening. On September 15, forty-seven days after the start of the feeding trial, the amount of corn and prairie hay for both lots was increased, and soybean meal decreased. A mixture of two parts salt and one part bone meal, with added trace minerals, was available to the lambs.

In Trial II, the feeding period started July 13, 1951, and continued for 99 days. The lambs were all Hampshire X fine-wool crossbreds. Forty-eight lambs were divided into four lots of 12 lambs each on the basis of body weight and sex. An average of two consecutive daily weights, each preceded by an overnight period without water, was used for the initial and final weights. Each lot contained 7 wethers and 5 ewe lambs at the start of the experiment. One wether lamb in Lot 3 went off feed during the first week of the trial and was removed from the experiment. The lambs were sheared and drenched with phenothiazine prior to the feeding trials.

The crude protein content of the basal ration fed in Trial II was considerably lower than that fed in Trial I. The lambs were fed a ration of ground shelled corn (full fed), beet pulp and prairie hay, with the following kinds and amounts of supplements per lamb daily:

Lot 1 -- 0.125 pounds of cottonseed meal.

Lot 2 -- 0.125 pounds of cottonseed meal plus 12.15 grams of urea ("262" commercial feeding compound).

Lot 3 -- 0.154 pounds of cottonseed meal plus 10.03 grams of urea ("262") as an average for the feeding trial. The level of urea was gradually increased during the first 30 days of the feeding trial, with a corresponding decrease in cottonseed meal nitrogen (see footnote 1, Table 26).

Lot 4 -- 0.29 pounds of cottonseed meal.

The crude protein content of the rations fed lambs of Lots 2, 3 and 4 were equal throughout the experiment. The amount of protein supplement was reduced in the rations of all lots after the first 50 days of the feeding period. Cottonseed meal in the daily rations for Lots 1, 2 and 3 was reduced from 0.17 to 0.08 pounds per lamb, and in Lot 4 from 0.33 to 0.25 pounds per lamb. The urea intakes of lambs in Lots 2 and 3 remained the same.

The calcium and phosphorus intakes on all rations were equalized by the addition of varying amounts of calcium carbonate and bone meal. Salt, containing one ounce of cobalt chloride per 100 pounds, was available to the lambs of all lots. Refused hay was weighed back once daily. The beet pulp was weighed out dry, moistened and allowed to stand for about 12 hours before feeding.

In both feeding trials, the lambs were kept at the experimental barn in pens which opened on small exercise lots, and were rotated among the pens at 10-day intervals. The lambs did not appear to be bothered excessively by the heat and appetites were satisfactory with the exception of one lamb in each experiment which went off feed. The lambs were sold on the Oklahoma City market at the completion of the feeding trials.

Results and Discussion

The average weight gains of the lambs and average daily rations fed during Trial I are shown in Table 24. The lambs of both lots gained nearly the same. Average gains in weight were 23.8 pounds for lambs of Lot 1, and 23.2 pounds for lambs of Lot 2 fed the urea ration. It was observed that the lambs of Lot 1, fed the basal ration, were easier to keep on feed as the experiment progressed than lambs fed the urea ration.

The basal ration fed Lot 1 contained 9.74 per cent crude protein and was apparently adequate in nitrogen. The addition of supplemental urea was not beneficial. Results of nitrogen balance studies (Experiment B, Part I) show that the addition of urea to rations containing 10 per cent crude protein did not increase the nitrogen retention of lambs and perhaps offers a basis for explaining the results obtained in this feeding trial.

The chemical composition of the feeds used in Trial II is shown in Table 25. The average weight gains of the lambs, daily rations fed, and financial returns are shown in Table 26.

The average weight gains of the lambs during the 99-day feeding period were 37.1, 36.6, 36.9, and 40.0 pounds for Lots 1, 2, 3, and 4, respectively. There was no significant difference in the weight gains of the lambs. The addition of urea to the ration of Lot 2 lambs did not result in greater gains, while the addition of cottonseed meal to the ration of Lot 4 lambs slightly

TABLE 24

Average Weights, Daily Rations, and Crude Protein Levels of Rations Fed Lambs During Trial I (July 31 to October 22, 1950)

	Lot 1 Basal	Lot 2 Basal + Urea
Number of lambs per lot	8	7[1]
Average weight (lbs.)		
Initial 7-31-50	50.6	52.4
Final 10-22-50	74.4	75.6
Total gain	23.8	23.2
Average daily gain	0.283	0.276
Average daily ration		
Ground shelled corn . . . . . lbs	1.38	1.38
Soybean meal. . . . . lbs.	0.057	0.057
Alfalfa hay . . . . lbs.	0.50	0.50
Prairie hay . . . . lbs.	0.65	0.65
Urea ("262") . . . . gms.		8.00
Crude protein in ration[2] . . . . %	9.74	11.51

[1] One fine-wool lamb in Lot 2 went off feed September 15 and is not included in these data.

[2] Crude protein contents of feeds used were as follows: alfalfa hay, 15.94%; corn, 8.57%, soybean meal, 43.56%, and prairie hay, 4.53% on an air-dry basis.

TABLE 25

Chemical Composition of Feeds Used in Trial II with Lambs

	Percent Dry Matter	Percentage Composition of Dry Matter					
		Ash	Crude Protein	Ether Extract	Crude Fiber	N.F.E.	P
Corn	89.32	1.48	8.46	4.75	1.98	83.33	0.33
Cottonseed Meal	94.51	6.80	44.97	3.65	12.54	32.04	1.16
Beet Pulp (dried)	91.30	2.98	8.93	0.47	22.72	64.91	0.05
Prairie Hay	92.37	9.68	4.70	1.86	33.70	50.06	0.07
Bone Meal	98.27	87.63	7.18	0.12		5.07	15.57

TABLE 26

Average Weights, Daily Rations Fed, Crude Protein Levels and Financial Returns for Lambs During Trial II (July 13 to October 20, 1951)

		Lot 1 Basal	Lot 2 Basal + Urea	Lot 3 Basal + Urea[1]	Lot 4 Basal + C.S. Meal
Number of lambs per lot		12	12	11	12
Average weight (lbs.)					
Initial 7-13-51		56.8	55.8	57.0	56.5
Final 10-20-51		93.9	92.4	93.9	96.5
Total gain		37.1	36.6	36.9	40.0
Average daily gain		0.37	0.37	0.37	0.40
Average daily ration					
Ground shelled corn	lbs.	1.58	1.56	1.54	1.56
Cottonseed meal	lbs.	.125	.125	.154	.29
Beet pulp (dried) . . . . . . ,	lbs.	.17	.17	.17	.17
Prairie hay	lbs.	.87	.86	.88	.87
Urea ("262")	gms.		12.15	10.03	
Calcium carbonate	gms.	5.2	5.2	6.0	7.7
Bone meal	gms.	4.9	4.9	3.4	
Salt	lbs.	.012	.012	.012	.012
Percent crude protein in ration		8.07	10.51	10.37	10.03
Feed required per cwt. gain (lbs.)					
Ground shelled corn		421	422	413	386
Cottonseed meal		33	34	41	72
Beet pulp (dried)		45	46	46	42
Prairie hay		232	233	236	215
Urea ("262")			7.2	5.9	
Feed cost per cwt. gain ($)[2]		15.03	15.65	15.54	15.31
Financial returns ($)					
Average selling price per cwt.		30.00	29.75	30.00	29.50
Total value per lamb		28.17	27.49	28.17	28.47
Feed cost per lamb		5.58	5.73	5.74	6.12
Return per lamb (market value-feed cost)		22.59	21.76	22.43	22.35

[1] Urea ("262") was increased at 10-day intervals during the first 30 days of the experiment as follows: 2.5 gm. per day for the first 10 days; 5 gm. per day for the second 10 days; 8.0 gm. per day for the third 10 days, and 12.15 gm. per day for the remainder of the feeding period. Cottonseed meal was decreased in nitrogen equivalent amounts with each addition of urea.

[2] Feed prices were: corn, $1.45 per bu.; cottonseed meal, $77.40 per ton; beet pulp, $78 per ton; prairie hay, $9.00 per ton; urea ("262"), $0.07 per lb.; salt, $.68 per cwt.; bone meal, $4.00 per cwt., and calcium carbonate, $0.70 per cwt.

increased the average gain. Gradually increasing the level of urea in the ration fed lambs of Lot 3 during the first 30 days of the feeding trial did not increase the ability of the lambs to utilize urea nitrogen.

These data are somewhat in agreement with the results of Willman, Morrison and Klosterman (1946) who found that when urea was the only nitrogen supplement in practical lamb-fattening rations, the gains obtained were unsatisfactory as compared to linseed meal supplemented rations. In further experiments, however, when urea was substituted for one-half the linseed meal in nitrogen equivalent amounts, the rate of gain was improved as compared to the check lot receiving the same amount of linseed meal without urea.

Although the lambs were fed all the corn they would consume, the average daily rations shown in Table 26 indicate that there was little difference in the appetites of the lambs. Lot 1 lambs, fed the low protein basal ration, consumed slightly more corn than lambs of the other lots. These results do not agree with experiments in which maintenance-type rations were fed (Glasscock et. al., 1950) and the addition of urea to low-protein rations increased the feed consumption of ruminants.

Feed required for each 100 pounds of gain was quite similar for lambs of Lots 1, 2, and 3. Lambs of Lot 4 required 35 pounds less corn, but 39 pounds more cottonseed meal, for each 100 pounds of gain than lambs fed the basal ration (Lot 1). The additional cottonseed meal fed Lot 4 resulted in a greater feed cost per lamb. Since the results indicate that the basal ration was adequate in protein for satisfactory gains, the additional gain made by lambs of Lot 4 may have been due to an increase in the energy content of their rations, rather than an increase in protein.

There was little difference in the financial returns per lamb (market value minus feed costs). All lambs sold for the same price ($30.00 per cwt.)

with the exception of one lamb in Lot 2 and two lambs in Lot 4. These lambs sold for $27.00 per cwt. and were among the slow-gaining lambs of their respective groups.

It is probable that the protein levels in the basal rations during both trials were too high for efficient use of urea nitrogen. However, if the protein level of the basal ration were dropped low enough to permit urea utilization, questions of a practical nature are raised. Low protein rations usually result in slow gains, poor economy of feed utilization, and often a decrease in the market value of the lamb. Unless urea can correct these disadvantages, as common protein supplments are able to do, the practical value of urea is questionable. Further trials are necessary as to the advisability of using urea in lamb-fattening rations which are critically low in protein.

Summary of the Utilization of Urea by Fattening Lambs

Two feeding trials were conducted with growing and fattening lambs (a) to determine the value of adding urea to a ration containing 9.7 per cent crude protein in amounts sufficient to raise the crude protein level to 11.5 per cent, and (b) to compare urea and cottonseed meal when added in nitrogen equivalent amounts to rations containing 8.1 per cent crude protein.

In both trials, the addition of urea to the basal ration failed to increase the weight gains of the lambs. In the second trial, the addition of nitrogen equivalent amounts of cottonseed meal slightly increased the rate of gain of the lambs, although this may have been due to the higher energy content of the cottonseed meal supplemented ration rather than an increase in protein. Gradually increasing the level of urea in the ration during the first 30 days of the feeding trial did not enhance the ability of the lambs to utilize urea under the conditions of this study. The data obtained suggest that the rations were adequate in protein for satisfactory gains, thus additional urea nitrogen was not utilized.

SUMMARY

Factors affecting the utilization of urea by sheep were studied in metabolism and feeding experiments. Nitrogen balance and digestion trials were conducted with lambs to determine (a) the relative value of urea and a new product, uramite, as nitrogen supplements to low protein rations differing in their content of low-quality roughage, (b) the efficiency of urea utilization when increasing amounts were added to a low-protein ration, (c) the value of methionine when added to a low-protein ration, and to a similar ration supplemented with urea, and (d) the effect of urea on the digestibility of the ration. Further trials were conducted with ewes to study the value of urea, in comparison to cottonseed meal, as a source of nitrogen during pregnancy and lactation. The relative value of urea and cottonseed meal in rations for fattening lambs in drylot was also investigated.

The results obtained in the metabolism studies indicate that urea is more efficiently utilized when added to rations low in poor quality roughage and high in readily available carbohydrate. Uramite was found to be an impractical supplement since it contains a high percentage of unavailable nitrogen. Urea was more efficiently utilized when added to a low-protein ration in amounts sufficient to raise the crude protein levels to 8.5 and 10 per cent than at the 12 per cent level. Cottonseed meal was utilized more efficiently than urea in a ration containing 12 per cent crude protein. The addition of small amounts of methionine to rations containing urea slightly improved nitrogen retention and ration digestibility. The addition of urea to low-protein rations consistently increased the digestibility of all ration

nutrients, with the exception of ether extract. A similar increase was obtained with cottonseed meal in nitrogen equivalent amounts.

In the first trial with pregnant and lactating ewes, urea proved to be an unsatisfactory source of nitrogen as compared to cottonseed meal when the relative value of the two supplements was measured by the weight gains of the ewes, weight of the lambs at 42 days and fleece weights. Inefficient use of urea in the ration was associated with relatively high blood and colostrum urea levels. When the concentrate mixtures were pelleted and fed at a higher level in the second trial, urea utilization was improved. Ewes fed urea pellets did not differ significantly in performance from ewes fed equal amounts of cottonseed meal pellets. Both groups were consistently superior in weight gains, fleece weights and lamb gains to the basal lot fed equal amounts of low-protein pellets. Blood and colostrum urea levels of ewes fed the urea and cottonseed meal pellets did not differ significantly, while ewes fed the cottonseed meal pellets had significantly higher hemoglobin levels.

In feedlot trials, supplementing the rations of fattening lambs with urea did not increase weight gains in two trials. Nitrogen equivalent amounts of cottonseed meal slightly increased the average gain of the lambs in one trial. Gradually increasing the level of urea in the ration at the expense of cottonseed meal during the first 30 days of the feeding trial did not enhance the ability of lambs to utilize urea nitrogen.

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APPENDIX

Daily Nitrogen Balance and Biological Value Data of Lambs in the Urea and Uramite Metabolism Study

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake: Dry Matter	Intake: N	Excretion: Fecal N	Excretion: Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	Biological Value
			lbs.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
High Hull													
Basal	2	5	63	644	7.43	5.93	1.86	-0.36	3.57	0.94	5.04		
	2	6	63	644	7.43	5.86	1.91	-0.34	3.57	0.94	5.11		
	2	8	68	644	7.43	5.94	2.41	-0.92	3.57	1.02	5.03		
		Ave.	65	644	7.43	5.91	2.06	-0.54	3.57	0.97	5.06		
Basal + Urea	4	5	64	657	10.64	6.12	4.88	-0.36	3.65	0.96	8.13		
	4	7	62	647	10.64	5.88	4.56	+0.20	3.65	0.93	8.37		
	6	6	62	653	10.93	6.70	4.70	-0.47	3.62	0.93	7.82		
	6	8	66	653	10.93	6.80	4.73	-0.60	3.62	0.99	7.72		
		Ave.	65	655	10.78	6.38	4.72	-0.32	3.63	0.97	8.01		
Basal + Uramite	4	6	62	658	10.64	7.69	2.59	+0.36	3.65	0.93	6.60		
	4	8	67	658	10.64	8.44	2.24	-0.04	3.65	1.00	5.85		
	6	5	64	654	10.93	8.17	3.28	-0.52	3.63	0.96	6.39		
	6	7	61	654	10.93	8.45	2.62	-0.14	3.63	0.91	6.11		
		Ave.	64	656	10.78	8.19	2.68	-0.09	3.64	0.95	6.24		
Medium Hull													
Basal	7	1	67	644	7.02	5.44	1.44	+0.14	3.54	1.01	5.12	4.69	
	7	2	64	644	7.02	5.10	1.40	+0.52	3.54	0.96	5.46	5.02	
	7	3	68	644	7.02	4.84	1.85	+0.33	3.54	1.02	5.71	4.89	
	7	4	68	644	7.02	5.53	1.44	+0.05	3.54	1.02	5.03	4.61	
		Ave.	67	644	7.02	5.23	1.53	+0.26	3.54	1.00	5.36	4.83	
Basal + Urea	3	2	64	651	10.35	5.61	4.05	+0.69	3.61	0.96	8.32	5.26	63
	3	4	64	651	10.35	5.70	3.75	+0.90	3.61	0.96	8.26	5.47	66
	5	1	66	651	10.46	5.58	4.07	+0.81	3.61	0.99	8.49	5.41	64
	5	3	69	651	10.46	5.83	4.81	-0.18	3.61	1.03	8.24	4.82	59
		Ave.	66	651	10.40	5.68	4.17	+0.55	3.61	0.98	8.33	5.15	62

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	Biological Value
			lbs.	gm	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
Basal + Uramite	3	1	62	652	10.35	7.05	2.19	+1.11	3.62	0.93	6.92	5.66	82
	3	3	68	652	10.35	7.02	2.57	+0.76	3.62	1.02	6.95	5.40	78
	5	2	65	651	10.46	7.98	2.43	+0.05	3.61	0.97	6.09	4.63	76
	5	4	67	651	10.46	7.98	2.14	+0.34	3.61	1.00	6.09	4.95	81
		Ave.	65	652	10.40	7.51	2.33	+0.56	3.62	0.98	6.51	5.16	79
Low Hull Basal	8	5	62	663	6.74	3.96	1.93	+0.85	3.68	0.93	6.46	5.46	
	8	7	60	663	6.74	4.28	1.35	+1.11	3.68	0.90	6.14	5.69	
	9	1	66	662	6.75	4.14	1.52	+1.09	3.67	0.99	6.28	5.75	
	9	3	69	662	6.75	3.96	1.52	+1.27	3.67	1.03	6.46	5.97	
	10	6	64	657	6.80	3.99	1.19	+1.62	3.65	0.96	6.46	6.23	
	10	8	69	657	6.80	3.89	1.70	+1.21	3.65	1.03	6.56	5.89	
	11	2	69	652	6.85	4.04	1.16	+1.65	3.62	1.03	6.43	6.30	
	11	4	72	652	6.85	4.22	1.59	+1.04	3.62	1.08	6.25	5.74	
		Ave.	66	658	6.78	4.06	1.50	+1.23	3.65	0.99	6.37	5.87	
Basal + Urea	8	6	61	672	10.51	4.27	3.73	+2.51	3.73	0.91	9.97	7.15	72
	9	2	66	671	10.52	4.48	4.09	+1.95	3.72	0.99	9.76	6.66	68
	10	5	64	666	10.57	4.00	4.31	+2.26	3.70	0.96	10.27	6.92	67
	11	1	71	661	10.62	4.30	3.81	+2.51	3.67	1.06	9.99	7.24	72
		Ave.	65	667	10.55	4.26	3.99	+2.31	3.70	0.98	9.99	6.99	70
Basal + Uramite	8	8	66	673	10.51	5.83	2.73	+1.95	3.74	0.99	8.42	6.68	79
	9	4	68	672	10.52	6.25	2.11	+2.16	3.73	1.02	8.00	6.91	86
	10	7	65	667	10.57	5.86	1.98	+2.73	3.70	0.97	8.41	7.40	88
	11	3	73	662	10.62	5.76	1.87	+2.99	3.67	1.09	8.53	7.75	91
		Ave.	68	668	10.55	5.92	2.17	+2.46	3.71	1.02	8.34	7.19	86
Medium Hay Basal	12	6	69	652	6.74	3.90	1.72	+1.12	3.62	1.03	6.46	5.77	
	13	8	73	652	6.74	3.43	1.48	+1.83	3.62	1.09	6.55	6.54	
		Ave.	71	652	6.74	3.66	1.60	+1.48	3.62	1.06	6.50	6.16	
Basal + Urea	12	8	69	661	10.51	3.74	3.83	+2.94	3.67	1.03	10.44	7.64	73
	13	6	70	661	10.51	4.27	3.93	+2.31	3.67	1.05	9.91	7.03	71
		Ave.	70	661	10.51	4.00	3.88	+2.63	3.67	1.04	10.17	7.34	72

TABLE 28

Apparent Digestion Coefficients of the Basal and Urea Rations
Fed Lambs in the Urea and Uramite Metabolism Study

:ation	Trial No.	Lamb No.	Dry Matter Intake	Apparent Percentage Digestibility of --					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
			gm.						
:igh Hull									
:asal	2	5	644	47.36	43.51	20.26	80.30	39.36	49.52
	2	6	644	46.43	43.35	21.12	80.30	42.48	46.72
	2	8	644	46.43	43.35	20.04	72.73	40.14	48.83
		Ave.	644	46.74	43.30	20.47	77.78	40.66	48.36
:asal +									
:rea	4	5	657	52.51	51.53	42.64	83.52	41.45	60.87
	4	7	657	47.34	46.55	44.89	86.81	38.93	52.91
	6	6	654	54.98	54.55	38.60	77.45	48.00	63.76
	6	8	654	54.52	53.43	37.87	69.61	49.14	61.26
		Ave.	656	52.34	51.52	41.00	79.35	44.38	59.70
:edium Hull									
:asal	7	1	644	50.62	50.06	22.60	93.39	25.97	59.52
	7	2	644	59.78	59.85	27.40	94.21	40.48	68.54
	7	3	644	59.16	59.23	31.05	93.39	38.29	68.00
	7	4	644	54.35	53.95	21.23	96.87	34.65	62.44
		Ave.	644	55.98	55.77	25.57	94.47	34.85	64.63
asal +									
rea	3	2	651	65.13	65.29	45.82	86.73	40.14	77.47
	3	4	651	64.21	64.45	44.74	82.30	35.53	77.08
	5	1	650	60.62	60.48	46.64	69.47	32.52	72.27
	5	3	650	62.31	62.43	44.19	65.65	35.73	74.61
		Ave.	651	63.07	63.16	45.35	76.04	35.98	75.38
ow Hull									
asal	8	5	663	68.78	68.45	41.09	88.46	13.16	78.91
	8	7	663	68.32	68.28	36.58	79.23	12.41	79.42
	9	1	662	68.12	68.05	38.72	84.17	13.35	78.38
	9	3	662	69.49	69.52	41.33	83.45	14.65	79.84
	10	6	659	65.12	65.03	41.18	66.67	7.41	75.94
	10	8	659	66.00	65.63	42.59	74.83	14.17	75.29
	11	2	652	72.35	72.27	40.85	80.00	27.83	81.70
	11	4	652	64.23	64.24	38.03	72.50	6.50	75.29
		Ave.	659	67.80	67.68	40.09	78.66	13.69	78.10
asal +									
rea	8	6	672	70.98	70.99	59.36	86.92	23.92	80.34
	9	2	671	72.28	72.35	57.38	84.17	19.90	62.76
	10	5	666	74.65	74.67	62.18	82.31	25.10	84.53
	11	1	661	75.62	75.77	59.37	81.25	32.50	85.30
		Ave	667	73.38	73.45	59.57	83.91	25.36	78.23
edium Hay									
asal	12	6	652	56.36	53.83	42.18	59.15	37.20	64.46
	13	8	652	62.69	60.39	49.05	67.07	50.60	68.38
		Ave.	652	59.53	57.11	45.62	63.11	43.90	66.42
asal +									
rea	12	8	661	68.04	66.57	64.44	63.41	56.10	74.74
	13	6	661	63.28	61.73	59.42	59.76	50.86	70.71
		Ave.	661	65.66	64.15	61.93	61.29	53.48	72.73

TABLE 29

Daily Nitrogen Balance and Biological Value Data of Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	Biological Value
			lbs.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
a. Basal													
	1	1	64	625	7.02	5.32	1.46	+0.24	3.47	0.96	5.17	4.67	
	2	6	57	624	7.17	4.97	1.37	+0.83	3.46	0.85	5.66	5.14	
	3	4	65	624	7.06	4.77	1.71	+0.58	3.46	0.97	5.75	5.01	
	4	9	59	624	7.01	5.07	1.35	+0.59	3.46	0.88	5.40	4.93	
		Ave.	61	624	7.06	5.03	1.47	+0.56	3.46	0.92	5.49	4.94	
b. Basal													
+ 3.3 gm.	1	5	62	628	8.44	5.51	1.28	+1.65	3.49	0.93	6.42	6.07	95
Urea	2	7	56	627	8.59	4.74	1.22	+2.63	3.48	0.84	7.33	6.95	95
	3	1	63	627	8.48	5.11	1.91	+1.46	3.48	0.94	6.85	5.88	86
	4	6	62	627	8.43	4.15	2.78	+1.50	3.48	0.93	7.76	5.91	76
		Ave.	61	627	8.49	4.88	1.80	+1.81	3.48	0.91	7.09	6.20	87
c. Basal													
+ 7.5 gm.	1	3	66	631	10.17	4.80	3.13	+2.24	3.50	0.99	8.87	6.73	76
Urea	2	8	64	631	10.32	4.68	3.31	+2.33	3.50	0.96	9.14	6.79	74
	3	5	61	631	10.21	5.50	2.20	+2.51	3.50	0.91	8.21	6.92	84
	4	2	70	631	10.16	5.18	1.58	+3.40	3.50	1.05	8.48	7.95	94
		Ave.	65	631	10.22	5.04	2.56	+2.62	3.50	0.98	8.68	7.10	82

TABLE 29 (continued)

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Bal-ance	Meta-bolic N	Endog-enous N	True Digested N	Absorbed N Utilized	Bio-logical Value
			lbs.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
d. Basal													
+ 13.1 gm.	1	4	65	636	12.49	4.58	5.52	+2.39	3.53	0.97	11.44	6.89	60
Urea	2	9	56	636	12.65	5.75	4.69	+2.21	3.53	0.84	10.43	6.58	63
	3	3	67	636	12.54	4.88	5.24	+2.42	3.53	1.00	11.19	6.95	62
	4	8	69	636	12.49	4.92	5.42	+2.15	3.53	1.03	11.10	6.71	60
		Ave.	64	636	12.54	5.03	5.22	+2.29	3.53	0.96	11.04	6.78	61
e. Basal													
+ 22 gm.	5	1	68	631	8.48	5.46	1.44	+1.58	3.50	1.02	6.52	6.10	94
C.S.M.	5	4	69	631	8.48	4.71	1.64	+2.13	3.50	1.03	7.27	6.66	92
	6	2	72	631	8.48	4.58	1.38	+2.52	3.50	1.08	7.40	7.10	96
	6	6	62	631	8.48	4.51	1.98	+1.99	3.50	0.93	7.47	6.42	86
		Ave.	68	631	8.48	4.82	1.61	+2.05	3.50	1.02	7.16	6.57	92
f. Basal													
+ 86 gm.	5	3	72	630	12.29	5.02	5.29	+1.98	3.50	1.08	10.77	6.56	61
C.S.M.	5	5	66	630	12.29	5.86	3.04	+3.39	3.50	0.99	9.93	7.88	79
	6	7	61	630	12.29	5.21	3.68	+3.40	3.50	0.91	10.58	7.81	74
	6	8	73	630	12.29	4.72	4.67	+2.90	3.50	1.09	11.07	7.49	68
		Ave.	68	630	12.29	5.21	4.17	+2.91	3.50	1.02	10.58	7.43	70

TABLE 30

Apparent Coefficients of Digestion for Rations Fed Lambs in the Metabolism Study on the Efficiency of Urea Utilization

Ration	Trial No.	Lamb No.	Apparent Percentage Digestibility of - Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
a. Basal								
	1	1	58.0	58.7	24.1	91.8	31.8	68.6
	2	6	52.6	53.1	30.9	95.4	11.5	65.4
	3	4	63.3	63.9	32.3	87.3	34.7	74.6
	4	9	55.9	56.4	27.7	88.5	21.6	67.9
		Ave.	57.7	58.0	28.8	90.8	24.9	69.1
b. Basal								
+ 3.3	1	5	62.8	63.6	34.8	89.3	43.8	71.8
gm. Urea	2	7	69.7	70.4	47.5	93.4	47.1	79.5
	3	1	67.0	67.8	39.8	96.3	38.2	79.0
	4	6	66.9	67.5	50.7	91.6	40.9	76.2
		Ave.	66.6	67.3	43.2	92.7	42.5	76.6
c. Basal								
+ 7.5	1	3	70.4	71.2	52.9	90.5	51.1	79.1
gm. Urea	2	8	74.9	75.5	54.8	93.5	55.5	89.9
	3	5	70.9	71.9	46.2	88.3	49.1	81.8
	4	2	66.9	67.5	49.0	90.4	42.0	76.8
		Ave.	70.8	71.5	50.7	90.7	49.4	81.9
d. Basal								
+ 13.1	1	4	74.6	75.6	63.3	92.2	57.2	82.7
gm. Urea	2	9	67.9	69.0	54.5	93.5	42.7	78.6
	3	3	73.5	74.4	61.0	86.3	50.4	84.0
	4	8	71.9	72.3	60.7	87.7	55.2	79.0
		Ave.	72.0	72.8	59.9	89.9	51.4	81.4
e. Basal								
+ 22 gm.	5	1	63.6	64.4	35.5	92.6	41.7	73.5
C.S.M.	5	4	66.2	66.8	44.3	93.4	37.5	77.2
	6	2	63.0	63.3	45.8	92.6	36.6	72.0
	6	6	68.7	69.4	46.6	92.9	43.7	78.8
		Ave.	65.4	66.0	43.1	92.9	39.9	75.4
f. Basal								
+ 86 gm.	5	3	71.5	72.5	59.1	92.5	54.4	80.3
C.S.M.	5	5	66.7	67.6	52.3	90.1	47.9	76.3
	6	7	71.7	72.6	57.6	91.5	58.5	79.5
	6	8	74.7	75.2	61.6	94.2	57.3	83.0
		Ave.	71.2	72.0	57.6	92.1	54.5	79.8

TABLE 31

Daily Nitrogen Balance and Biological Value Data of Lambs in the Urea and Methionine Metabolism Study

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	Biological Value
			lbs.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
m. Urea													
	11	1	71	631	10.15	3.89	4.72	+1.54	3.50	1.06	9.76	6.10	63
	11	3	78	631	10.15	4.14	4.87	+1.14	3.50	1.17	9.51	5.81	61
		Ave.	75	631	10.15	4.01	4.79	+1.35	3.50	1.11	9.63	5.96	62
n. Urea													
+ Meth.	11	4	75	633	10.19	3.91	4.94	+1.34	3.51	1.12	9.79	5.97	61
	11	5	73	633	10.19	3.89	4.31	+1.99	3.51	1.09	9.81	6.54	67
		Ave.	74	633	10.19	3.90	4.62	+1.67	3.51	1.11	9.80	6.29	64
o. Urea													
	12	2	84	823	13.22	6.97	4.23	+2.02	4.57	1.26	10.82	7.85	73
	12	6	75	823	13.22	6.71	5.05	+1.46	4.57	1.12	11.08	7.15	64
	13	4	81	823	13.57	5.48	4.82	+3.27	4.57	1.21	12.66	9.05	71
	13	5	79	823	13.57	6.79	4.13	+2.65	4.57	1.18	11.35	8.40	74
	14	2	90	893	14.73	7.02	5.20	+2.51	4.96	1.35	12.67	8.82	70
	14	6	77	893	14.73	7.02	4.40	+3.31	4.96	1.15	12.67	9.42	74
		Ave.	81	846	13.84	6.67	4.64	+2.53	4.70	1.21	11.87	8.44	71
p. Urea													
+ Meth.	12	7	77	823	13.28	5.37	4.04	+3.87	4.58	1.15	12.49	9.60	77
	12	8	90	823	13.28	5.12	4.58	+3.58	4.58	1.35	12.74	9.51	75
	13	1	80	823	13.57	6.23	4.49	+2.85	4.58	1.20	11.92	8.63	72
	13	3	85	823	13.57	6.70	5.23	+1.64	4.58	1.27	11.45	7.49	65
	14	7	83	896	14.80	7.04	5.15	+2.61	4.97	1.24	12.73	8.82	69
	14	8	94	896	14.80	6.02	5.91	+2.87	4.97	1.41	13.75	9.25	67
		Ave.	85	847	13.88	6.08	4.90	+2.90	4.71	1.27	12.51	8.88	71

TABLE 31 (continued)

Ration	Trial No.	Lamb No.	Lamb Wt.	Intake Dry Matter	Intake N	Excretion Fecal N	Excretion Urinary N	N Balance	Metabolic N	Endogenous N	True Digested N	Absorbed N Utilized	Biological Value
			lbs.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	%
q. Low Protein	15	1	83	883	10.18	5.89	1.97	+2.32	4.90	1.24	9.19	8.46	92
	15	3	87	883	10.18	6.98	1.94	+1.26	4.90	1.30	8.10	7.46	92
	16	2	96	883	9.71	6.41	2.53	+0.77	4.90	1.44	8.20	7.11	87
	16	6	82	883	9.71	6.81	2.30	+0.60	4.90	1.23	7.80	6.73	86
	17	5	87	883	9.88	6.94	2.07	+0.87	4.90	1.30	7.84	7.07	90
	18	7	89	883	10.49	6.74	2.15	+1.60	4.90	1.33	8.65	7.83	90
	18	8	101	883	10.49	6.10	2.21	+2.18	4.90	1.51	9.29	8.59	92
	19	3	95	883	10.16	6.73	1.87	+1.56	4.90	1.42	8.33	7.88	95
		Ave.	90	883	10.10	6.58	2.13	+1.39	4.90	1.35	8.42	7.64	91
r. Low Protein + Meth.	15	5	85	886	10.35	6.44	2.25	+1.66	4.92	1.27	8.83	7.85	89
	16	7	87	886	10.03	6.83	2.62	+0.58	4.92	1.30	8.12	6.80	84
	16	8	99	886	10.03	6.36	2.55	+1.12	4.92	1.48	8.59	7.52	87
	17	1	85	886	10.20	6.03	2.10	+2.07	4.92	1.27	9.09	8.26	91
	17	3	90	886	10.20	6.84	2.06	+1.30	4.92	1.35	8.28	7.57	91
	18	2	98	888	11.01	6.21	2.74	+2.06	4.93	1.47	9.73	8.46	87
	18	6	84	888	11.01	7.41	2.87	+0.73	4.93	1.26	8.53	6.92	81
	19	5	91	888	11.29	6.60	2.66	+2.03	4.93	1.36	9.62	8.32	86
		Ave.	90	887	10.52	6.59	2.48	+1.45	4.92	1.35	8.85	7.72	87

TABLE 32

Apparent Digestibility of Rations Fed Lambs in the Urea and Methionine Metabolisn Study

Ration	Trial No.	Lamb No.	Apparent Percentage of Digestibility of - Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N.F.E.
m. Urea								
	11	1	72.5	73.3	61.7	92.4	51.4	80.7
	11	3	74.4	74.9	59.2	93.9	56.7	81.8
		Ave.	73.5	74.1	60.5	93.2	54.1	81.3
n. Urea								
+ Meth.	11	4	76.6	76.9	61.6	95.2	58.6	83.8
	11	5	74.0	74.8	61.8	92.0	58.6	80.7
		Ave.	75.3	75.9	61.7	93.6	58.6	82.3
o. Urea								
	12	2	69.9	70.5	47.4	91.4	43.1	81.2
	12	6	63.9	64.3	49.2	91.9	36.5	73.6
	13	4	74.9	75.1	59.6	96.5	54.0	82.7
	13	5	70.0	70.1	49.9	92.4	50.7	78.1
	14	2	66.9	67.8	52.3	84.8	35.3	79.0
	14	6	61.8	61.8	52.3	88.0	25.3	72.8
		Ave.	67.9	68.3	51.6	90.8	40.8	77.9
p. Urea								
+ Meth.	12	7	69.7	70.1	59.4	90.7	47.9	77.4
	12	8	75.5	75.6	61.4	94.2	57.6	82.2
	13	1	67.4	68.0	54.2	95.3	37.4	77.9
	13	3	68.3	69.2	50.5	77.3	47.3	78.3
	14	7	69.2	70.1	52.5	86.4	43.1	80.1
	14	8	74.7	74.8	59.3	90.9	52.6	83.1
		Ave.	70.8	71.3	56.2	89.1	47.7	79.8
q. Low								
Protein	15	1	61.4	61.7	42.1	93.3	37.0	69.5
	15	3	60.9	61.1	31.6	89.7	36.9	69.8
	16	2	59.7	59.9	34.2	87.9	24.1	71.4
	16	6	60.0	60.4	29.9	90.0	27.0	71.6
	17	5	57.5	57.5	29.8	95.9	22.6	68.6
	18	7	59.0	59.1	35.8	89.9	32.5	68.0
	18	8	69.9	69.8	41.8	86.3	53.2	76.9
	19	3	64.6	64.8	33.2	91.7	36.1	75.1
		Ave.	61.6	61.8	34.8	90.6	33.7	71.4
r. Low								
Protein	15	5	54.2	53.9	37.9	91.9	23.5	62.6
+ Meth.	16	7	57.9	58.3	31.9	88.8	27.3	68.5
	16	8	66.7	66.5	36.6	91.2	34.0	77.7
	17	1	61.1	61.3	40.8	94.0	25.5	73.3
	17	3	61.9	62.1	32.8	92.8	33.9	71.8
	18	2	64.8	64.8	43.6	91.1	41.5	72.8
	18	6	55.4	55.4	32.8	86.7	27.7	64.5
	19	5	59.6	59.5	41.5	93.7	28.4	69.1
		Ave.	60.2	60.2	37.2	91.3	30.2	70.0

TABLE 33

Ewe Weights, Fleece Weights and Lamb Production Records
for Trial I, the 1949-50 Study

		Ewe Weights							Lamb Weights				
Lot No.	Ewe No.	Initial Dec. 10	Last Wt. Before Lambing	After Lambing	42 Days After Lambing	Lambing Date	Breed of Lamb[a]	Sex of Lamb	At Birth	10 Days	21 Days	42 Days	Fleece Weight
		lbs.	lbs.	lbs.	lbs.				lbs.	lbs.	lbs.	lbs.	lbs.
1	1233	99	97	79	85	2/19	F.W.	Ram	7.8	10.0	11.8	18.0	9.6
	1259[b]	112	111	99		3/11	F.W.	Ram	9.0				7.5
	1249	85	93	78	77	3/12	F.W.	Ewe	6.8	9.5	13.0	19.3	9.5
	1234	105	111	94	83	3/30	CrB.	Ram	8.8	12.5	15.0	18.0	9.8
	1257[c]	107	120	100		4/2	CrB.	Ewe	8.0				
							CrB.	Ram	6.0				
	1231[c]	123	108	98		4/12	CrB.	Ewe	6.3				
	1260	101	109	95	88	4/13	CrB.	Ram	8.0	7.8	12.8	19.0	8.8
	1241[c]	92	92	76		4/13	CrB.	Ewe	8.0				
	1258	112	119	100	84	4/14	CrB.	Ram	11.5	14.0	15.8	20.0	7.0
	1253[d]	113	126										

[a] F. W. refers to fine-wool lambs, CrB. refers to crossbred lambs.

[b] Lamb born normally but froze to death.

[c] Ewe died after lambing.

[d] Ewe died prior to lambing, twin fetuses.

		Ewe Weights							Lamb Weights				
Lot No.	Ewe No.	Initial Dec. 10	Last Wt. Before Lambing	After Lambing	42 Days After Lambing	Lambing Date	Breed of Lamb[a]	Sex of Lamb	At Birth	10 Days	21 Days	42 Days	Fleece Weight
		lbs.	lbs.	lbs.	lbs.				lbs.	lbs.	lbs.	lbs.	lbs.
2	1235[e]	129	118	105		3/31	CrB.	Ram	7.0				11.3
	1245	126	110	110	98	3/4	F.W.	Ewe	7.5	11.5	14.5	18.5	10.5
								Ewe	5.3	9.0	12.5	16.5	
	1251[c]	113	112	99		3/27	CrB.	Ram	6.3				
	1243[f]	105	105	82		3/8	F.W.	Ram	5.5				6.8
								Ram	5.5				
	1238[d]	101	99	83									
	1256	104	111	94	102	3/9	F.W.	Ram	9.8	14.0	18.8	20.3	8.4
	1247	106	113	98	101	3/8	F.W.	Ram	8.0	11.0	15.3	23.0	9.8
	1242	101	113	97	90	4/3	CrB.	Ewe	8.3	12.5	16.0	23.5	10.1
	1236	95	95	84	92	3/10	F.W.	Ram	7.3	9.0	11.3	15.5	10.8
	1239	87	104	91	84	3/31	CrB.	Ram	7.8	12.0	15.0	22.5	8.4
3	1246	125	145	123	125	4/3	CrB.	Ewe	10.5	15.8	19.5	28.8	11.8
	1254	118	144	113	113	3/8	F.W.	Ram	9.0	12.0	16.0	22.5	8.7
								Ewe	8.0	10.8	14.3	20.0	
	1232	114	129	112	88	3/9	F.W.	Ewe	10.8	16.5	24.0	36.0	9.1
	1252	115	137	118	101	3/31	CrB.	Ewe	10.0	13.3	15.3	24.0	11.0
	1244	105	126	106	99	3/31	CrB.	Ram	10.5	15.5	21.5	31.0	9.9
	1250	107	118	104	89	3/4	F.W.	Ewe	5.5	9.0	12.5	19.0	12.0
								Ram	5.3	8.8	11.0	15.3	
	1240	105	124	122	100	4/1	CrB.	Ewe	7.5	12.3	17.5	25.0	10.8
	1255	101	115	100	98	4/9	CrB.	Ewe	9.5	16.8	20.3	27.5	8.9
	1237	93	112	102	84	3/29	CrB.	Ram	12.0	16.5	20.0	26.8	8.5
	1248[b]	92	96	82		3/28							10.9

[a] F. W. refers to fine-wool lambs, CrB. refers to crossbreds.

[b] Ewe aborted shortly before term., single fetus.

[c] Ewe died after lambing.

[d] Ewe died prior to lambing, twin fetuses.

[e] Lamb born weak, died shortly afterward.

[f] Ewe failed to milk, unable to raise lambs.

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Ewe Weights, Fleece Weights and Lamb Production Records for Trial II, the 1950-51 Study

Lot No.	Ewe No.	Ewe Weights: Initial Nov. 20 lbs.	Ewe Weights: Last Wt. Before Lambing lbs.	Ewe Weights: After Lambing lbs.	Ewe Weights: 42 Days After Lambing lbs.	Lambing Date	Sex of Lamb	Lamb Weights[a]: At Birth lbs.	Lamb Weights[a]: 5 Days lbs.	Lamb Weights[a]: 10 Days lbs.	Lamb Weights[a]: 21 Days lbs.	Lamb Weights[a]: 42 Days lbs.	Fleece Weight lbs.
1	3072	104	120	107	110	2/26	Ewe	8.5	12.5	14.0	18.5	26.3	6.5
	3082[b]	106	121	97		3/5	Ewe	7.0					
							Ewe	9.0					
	3100	110	128	104	91	3/5	Ewe	8.5	10.8	12.5	15.3	22.0	6.2
							Ewe	7.5					
	3067	112	132	102	105	3/5	Ewe	8.8	13.0	15.0	22.0	31.0	8.0
	3075	100	113	98	87	3/6	Ram	10.3	14.0	16.5	20.0	30.0	5.2
	3086	112	129	112	87	3/18	Ram	10.0	13.5	15.0	17.5	21.0	8.5
	3079	103	127	110	106	3/20	Ram	11.5	13.5	15.3	17.5	24.0	8.0
2	3099	95	118	104	99	3/2	Ram	10.5	14.0	16.5	23.5	23.0	7.0
	3066	104	127	102	99	3/3	Ewe	8.3	12.0	16.0	19.7	32.0	9.5
							Ram	8.0					
	3070	111	140	127	116	3/5	Ram	11.5	14.0	16.3	22.3	36.0	9.0
	3074	112	141	121	91	3/12	Ewe	9.8	14.3	16.5	22.8	34.0	9.3
	3089	118	147	121	114	3/11	Ewe	6.5	11.5	13.3	18.5	30.5	9.4
							Ram	5.8					
	3087	106	135	112	115	3/13	Ram	10.5	12.8	15.3	21.0	29.0	10.0
	3094	104	120	99	114	3/13	Ram	7.8	9.8	11.8	16.0	24.0	8.0
							Ram	7.0					
	3068	100	124	110	101	3/17	Ram	11.0	14.0	17.5	23.5	36.0	8.5

[a] Ewes with twin lambs given the largest lamb to raise as a single.

[b] Ewe developed udder trouble, was unable to raise a lamb.

TABLE 34 (continued)

Lot No.	Ewe No.	Ewe Weights: Initial Nov. 20	Last Wt. Before Lambing	After Lambing	42 Days After Lambing	Lambing Date	Sex of Lamb	Lamb Weights: At Birth	5 Days	10 Days	21 Days	42 Days	Fleece Weight
		lbs.	lbs.	lbs.	lbs.			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	3084	103	128	106	109	2/28	Ram	10.0	13.0	14.5	19.3	31.0	9.4
	3069	112	137	116	112	3/4	Ewe	10.0	13.5	18.0	26.0	34.5	9.4
	3098	105	132	113	111	3/8	Ram	11.5	14.5	20.0	26.5	40.5	9.7
	3073	114	139	120	114	3/10	Ewe	9.8	13.8	16.8	23.0	31.0	10.8
	3090[a]	111	139	112		3/12	Ewe	11.5					
	3078	109	138	118	123	3/13	Ewe	10.0	12.8	15.3	21.0	29.0	8.0
	3093	104	130	112	103	3/16	Ram	11.3	14.5	17.3	24.8	36.0	6.5
	3081	106	138	111	103	3/20	Ewe	7.5	11.0	14.0	16.5	30.0	9.0
							Ram	7.8					
	3097	99	131	114	101	3/27	Ram	8.5	11.5	13.5	17.0	29.0	9.5

[a] Ewe had difficulty lambing, lamb dead at birth.

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THESIS ADVISER: C. K. WHITEHAIR

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