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Digestibility of Rations and Nitrogen Balance by Lambs as Influenced by Animal Fat, Urea, Soybean Meal and Linseed Meal

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DIGESTIBILITY OF RATIONS AND NITROGEN BALANCE BY LAMBS AS INFLUENCED BY ANIMAL FAT, UREA, SOYBEAN MEAL AND LINSEED MEAL

By

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AND LINSEED MEAL

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Within the last few years, the production of rendered animal fats within the animal industry has created a considerable oversupply of these products in the United States. Estimates concerning this surplus by 1957 are in excess of 1.1 billion pounds (Ewell, 1953). Accordingly, the price outlook for lard and tallow has been such as to arouse considerable interest in these products as cheap sources of energy in livestock feeds. The caloric value of fat in the diet is approximately two and one-fourth times that of either carbohydrates or protein; and at the present market price, lard and tallow are being used as competitive sources of energy in many commercial rations for livestock. While ruminants seem to have less ability than other farm animals to utilize large amounts of fat from the diet, they are generally capable of using more than is normally present in most rations (Morrison, 1948). This is particularly true since the swing to solvent extraction of many of the oil meals produced for livestock feeds.

Feed processing and handling of livestock feeds have benefited from the use of fats in many ways. Reduced dustiness of feeds, reduced waste, decreased machinery wear, and increased ease of pelleting are but a few of the advantages. Nutritionally speaking, several reasons in favor of the use of stabilized animal fats in feeds have been reported. They include increased feed efficiency, improved appearance and palatability of the feeds, and increased vitamin stability. However, the optimum level and value of added fats in the rations for ruminants are not well established and further work is needed. It is known that fat is absorbed more slowly from the intestine than either carbohydrates or protein, and this may be an important factor in the utilization of added fat in the diet.

The use of urea as a replacement for a portion of the protein nitrogen in rations for ruminants has been clearly demonstrated and is now an established practice, when price allows for competition with other high protein sources. The mode of action of urea appears to be a synthesis of protein from non-protein material by the rumen microorganisms, and a digestion of these organisms farther down in the digestive tract (Reid, 1953). Research with urea as a protein sparer has been widespread, and its potential is more closely defined than is that of added fat in the ration. Both urea and fat are being used in some commercial feeds. It has been shown that urea is more efficiently utilized in protein synthesis with starch than with sugar. The effects of high levels of fat on urea utilization need to be determined if they are to be used together in ruminant feeds.

The work reported herein is a part of a project designed to determine the effect of lard, urea, soybean meal, and linseed meal upon the digestibility of rations and nitrogen balance by lambs. Rations testing these factors singularly and in combination were employed in an attempt to gain a more concise picture of the action of these factors upon the digestibility of the other nutrients in these rations. Late-cut prairie hay was fed as the source of roughage since its low protein content required the use of a high percentage of protein in the concentrate portion of the ration. The measures of performance were digestibility of crude protein, ether extract, crude fiber, nitrogen-free extract, and organic matter of the rations, and nitrogen balance of the lambs involved.

REVIEW OF LITERATURE

The Value of Adding Fat to Ruminant Rations

In the last few years, considerable research on fat as a source of energy in rations for livestock has been reported. This has resulted largely from an oversupply of lard, tallow, and vegetable oils and thus has been an attempt to utilize these surplus and "inedible" products in livestock feeds. Fat has long been considered the most concentrated source of energy in the animal body, but it has been only within the last few decades that it has been recognized as being essential for normal growth and development. The importance of fat in diets of humans and many experimental animals has been established and an extensive accumulation of literature has resulted in this field. This review of literature is confined to the work with fats in the field of ruminant nutrition, and more particularly the effect on growth and feed utilization.

Cattle

Some of the earlier studies on the value of adding fats to rations for livestock were concerned with the influence of kind and amount of fat in the rations for young dairy calves. Extensive work reported by Gullickson *et al.* (1939, 1942) demonstrated the effect of various animal and vegetable fats as substitutes for butterfat. Results of the early trials (1939) showed a superiority of butterfat over all the fats tested, although calves fed rations containing lard made nearly as rapid gains. The general appearance of the animals, however, was inferior to those receiving butterfat. Trials concluded in 1942 tested soybean oil, corn oil, cottonseed oil, peanut oil, lard, tallow, and butterfat. These were fed at the rate of 3.5 pounds to every 96.5 pounds of skim milk. Rate of gain and general appearance of the calves were in agreement with the former report, and the conclusions drawn from the experiment were that fats of animal origin were superior to those of vegetable origin for feeding young dairy calves.

Johnson et al. (1955) fed a pelleted calf starter containing levels of 0, 2.5, 5.0, and 10.0 percent stabilized tallow in rations to male Holstein calves. Calves fed tallow made five to ten percent greater increases in growth and feed efficiency was also greater. The greater increase in growth might have resulted from the consumption of more total digestible nutrients which were higher in the tallow rations. Values obtained from blood plasma analyses of all animals indicated that carotene and tocopherol utilization was unaffected by the inclusion of tallow in the diet. Digestibility studies with several of the calves, and also lambs, showed that the added tallow decreased the digestibility of protein, nitrogen-free extract, organic matter, and dry matter in the rations. Calcium content of the feces increased with the inclusion of tallow in the rations.

Much of the recent research on the use of surplus and waste fats in cattle feeding has been with fattening rations. Studies have been made on the energy value and acceptability by cattle of high-fat rations and the effects of the high levels of fat on the utilization of other nutrients. Erwin et al. (1956) used 48 yearling steers to test the digestibility of rations containing tallow. A pelleted ration consisting of 82 percent ground alfalfa, 11 percent concentrates, and 7 percent tallow was fed for

183 days. This experiment revealed that the use of tallow at the rate of 7 percent of the total rations significantly reduced the digestibility of crude fiber and dry matter.

Feed-lot performance of steers fed rations containing cottonseed oil were conducted by Willey *et al.* (1952). Two levels of added fat, 2.9 and 7.5 percent, were used to test the effect of different energy levels in rations. The use of the 7.5 percent level of added fat in the rations increased feed efficiency per 100 pounds of gain by approximately 13 percent, although there was no difference in the rate of gain or carcass grade of the animals. It was noted, however, that steers fed the high level of added fat did not possess as much fat in the rib cut and the loin eye muscle, but contained a higher percentage of lean. The high-fat rations improved the absorption of dietary carotene and tripled the level of fat in the blood. Depot body fat of animals fed added fat at both levels seemed to be more saturated in nature than for steers not receiving the added fat.

Matsushima and Dowe (1953) replaced 50 percent of the corn with beef tallow in rations utilizing high amounts of roughage. Steers fed rations containing tallow were heavier at market than were those animals on control rations. Vitamin A deficiency was noted among the groups fed tallow, which was attributed to the tallow being unstabilized, thus resulting in rancidity and vitamin A destruction. This trouble was overcome by adding a fat stabilizer to the rations. H. A. Armstrong (1954) of the American Meat Institute Foundation has shown that the vitamin content of feeds is well preserved when added fats have been stabilized.

Hentges *et al.* (1954) presented data covering two trials using waste beef tallow in fattening rations for steers. Results of the first trial indicated that 5.0 percent added tallow resulted in an increase in the average daily gain of 0.5 pounds per day over the animals fed similar rations without tallow. In the second trial, levels of 0, 5.0, and 10.0 percent added tallow were used. In terms of rate of gain, the 5.0 percent level again gave higher values than the basal ration, while the 10.0 percent level definitely reduced the rate of gain of the steers. Both of the tallow-fed groups appeared to have better feed efficiency than did those animals receiving the basal ration.

Sheep

Cunningham and Loosli (1954) conducted two investigations to determine if lambs and kids require a source of dietary fat and attempted to establish if the rumen of these animals could synthesize the essential fatty acids. In the first experiment, the animals were started on a ration of good alfalfa hay and oats and were gradually changed over to a fat-free, purified diet. Difficulty was reported in getting the animals to reach the desired caloric intake, with some bloating and going "off feed" resulting. There were, however, no symptoms of fatty acid deficiency reported. It was thought that previous storage of lipids was sufficient to prevent a deficiency from being noted in this experiment.

A second experiment was conducted to test fat-free rations against those containing lard. A synthetic milk basal ration was employed, with 25 grams of lard added per kilogram of milk and fed to those animals receiving the fat ration. Average milk intake for those lambs receiving added fat was about one kilogram per day, while the intake for those lambs on the fat-free diet averaged 755 grams per day. Lambs on the fat-free ration showed only slight weight gains, while those receiving lard made an average daily gain of 119 grams. A peculiar syndrome was noted among the fat-free groups from three to seven weeks after the start of the experiment. The animals suddenly exhibited muscular incoordination and would collapse on the front legs, with repeated efforts to rise weakening the animals. Twitching of the legs and entire bodies and a continual chewing movement of the jaws were also noted. Death of these animals usually followed within a few weeks. Young goats also showed these symptoms, only earlier in the treatment. Thiamine injections had no apparent affect upon any of the symptoms. Levels of 2.5 grams of lard or 3.6 and 5.5 grams of linoleic acid per kilogram of milk was found to be sufficient to prevent the occurrence of the symptoms. It was thus suggested that the synthesis of the essential fatty acids by lambs and kids from fat-free media was probably extremely limited.

In vitro studies with rumen microorganisms, using added fat, have also been reported. Work by Brooke *et al.* (1953) indicated that the fat level of the diet had a critical effect upon cellulose breakdown by the microorganisms found in the rumen of sheep. The addition of 10 milligrams of corn oil to the basal media decreased cellulose digestion five percent. The addition of more corn oil to the artificial rumen continued to significantly depress cellulytic digestion up to 75 percent. In a later report, Brooks *et al.* (1954) noted that corn oil added to a purified diet of casein, urea, and ammonium carbonate did not emulsify in the artificial rumen, but formed a layer. This might be a significant factor in limiting *in vitro* cellulose digestion when the fat content of rations rise above a certain optimum level. The reduction of protein digestibility was also reported in this investigation when corn oil was added to the media. The total number of bacteria in the rumen apparently was not reduced by the addition of the oil, but there was a definite change in the number of small rod and cocci bacteria when fat was present.

Hale and King (1955), at the Iowa Agricultural Experiment Station, presented evidence that 4.0 percent added fat had little, if any, effect upon the digestibility of dry matter in rations for lambs. Corn oil, tallow, and hydrogenated animal fat were used, each at four levels. The two high levels (8.0 and 12.0 percent) markedly reduced the digestibility of dry matter, and corn oil was reported to reduce digestibility to a higher degree than did tallow. The apparent digestibility of the fats used varied considerably; 92 percent for tallow, 80 percent for corn oil, and 64 percent for the hydrogenated animal fat.

Swift et al. (1947) supplemented rations containing 2.8 percent ether extract with levels of 32 and 64 grams of corn oil per day. Lambs receiving the rations containing 32 grams of added fat per day had significantly higher digestion coefficients for each of the major nutrients. The higher level of added fat, however, reduced the digestibility of all nutrients below that of the basal group. A similar trial has been reported by Brooks et al. (1954). Lambs receiving 32 grams of lard daily digested 33 percent less cellulose than did those on the basal ration. There was little change in the digestibility of protein at this level of added fat. However, lambs receiving 64 grams of lard per day digested 33 percent less crude protein and cellulose digestibility was reduced 53 percent. The volatile fatty acid concentration in the rumen contents also appeared to be lower when fat was added to the ration. It would appear that differences in the digestibility of various fats and oils play a major part in the digestibility and utilization of rations containing large amounts of roughage. Factors such as weight, age, and length of time on experiment may also contribute to the results obtained in any one trial. These reports would seem to indicate that large amounts of fat should not be used in rations high in fiber or cellulose, if maximum utilization of these materials are desired.

Kammlade and Butler (1954) used rendered animal fats to replace different amounts of grain in rations for lambs. Levels of 0, 5.0, 10.0, and 15.0 percent added fats were used. The replacement of carbohydrates, pound for pound, with fats resulted in higher energy rations than that of the basal ration. From the results, it appeared that added grease and tallow at the 5.0 percent level promoted significantly greater feed-lot gains and carcass weights. Feed efficiency was also improved by about 11 percent. Firmer carcasses were also noted in the lambs fed rations containing low levels of fat. The higher levels of added fat produced significantly softer body fat than the other levels, and they were considered as being in excess of the optimum level to be used in ruminant feeds.

Mason et al. (1955) added stabilized beef tallow in wintering rations to pregnant yearling ewes. Levels of 4.5 and 9.5 percent fat were used. Feed consumption of ewes fed tallow was not normal and the authors indicated that the added fat may have been responsible for the unpalatable nature of those rations. Satisfactory gains, however, were reported for all animals fed the tallow rations. The wool of the ewes receiving fat possessed more yolk and the ewes produced heavier lambs at birth, which seemed to grow more rapidly than lambs from the control animals. The only problem encountered in feeding tallow was that of the palatability of the rations containing fat at the levels used. When the level of added fat was reduced to 3.0 percent (Kercher et al. 1956), palatability of the rations was not influenced by the added fat.

The results of several experiments reviewed herein seem to indicate that beef tallow and lard are satisfactory energy substitutes in lamb and steer rations, up to 10 percent of the total ration. Levels of 4.0 and 5.0 percent added fat appear to give the best and most consistent results. However, the apparent variation between the digestibility of various fats and oils is one factor that will influence the value of rations to which fats are added, and further work on this is needed. Fats have been shown to increase the protein digestibility and the energy value of rations, and this is an important consideration in the formulation of feeds. The depression of crude fiber and cellulose digestibility of rations containing added fats indicate that the type of ration is a major factor in determining the success by which added fats ere utilized by ruminants. Due to the variability of the data presented, it is clear that further work is needed to clarify the conditions and optimum levels by which animal fats and vegetable oils may be added to ruminant rations.

The Value of Urea as a Protein Substitute in Rations for Ruminants

The use of urea to replace a part of the protein in rations for ruminants has received widespread investigation within recent years. Results have shown that urea and other non-protein, nitrogenous substances are utilized principally through bacterial action in the rumen. These microorganisms possess the ability to use urea and other non-protein sources of nitrogen to synthesize protein, and thus non-protein nitrogen becomes available to the ruminant largely as bacterial protein. Pearson and Smith (1943) noted that the rate of disappearance of urea from the rumen was associated with a corresponding rise of ammonia, and it was thus suggested that urea is converted to ammonia, and then synthesized by the microorganisms into protein.

The amount and source of protein supplied by the ration has been reported to be a major factor in the utilization of urea. Wegner et al. (1941) found that rations for cattle containing more than 18 percent protein caused a marked decrease in the utilization of urea. This was especially true when linseed meal was fed with urea.

Hamilton et al. (1948) reported that rations containing 16.2 percent protein, of which over 60 percent was from urea, were less efficiently utilized than those containing 11.2 percent protein. Nitrogen from urea rations, however, appeared to be as well digested as other sources of nitrogen in the rations for growing lambs, provided that the protein content of the rations did not exceed 12 percent. They also pointed out that at least one-fourth of the protein equivalent of rations needed to be supplied by preformed or conventional protein for maximum utilization of urea nitrogen.

Harris and Mitchell (1941a, 1941b) have conducted extensive research with urea and its effect upon maintenance and growth of lambs. Dry matter and crude fiber digestibility were improved when urea was added to a ration low in nitrogen. Urea was also shown to affect a positive nitrogen balance in lambs previously rendered negative. Nitrogen from casein brought about the same results as did urea. Twenty-three lambs were used in testing the value of urea and of casein in rations designed for growth. Rations of 11.0 and 15.0 percent protein equivalent were used, with urea and casein supplying up to 50 percent of the nitrogen of the rations. Lambs fed urea rations made normal or nearly normal rates of growth, and no toxicity toward urea was noted at the levels used. The results indicated that urea is satisfactory for use in rations designed for growth of lambs, provided that the rations contained no more than 11.0 percent protein.

The most favorable reports concerning the use of urea in ruminant rations have occurred when urea was used as only a partial substitute for protein. The levels of protein which have consistently prompted the best utilization of urea have been from 10 to 12 percent. Pope et al. (1951), however, reported that pregnant ewes gained more weight during gestation and produced heavier lambs at birth when fed urea-containing rations of 14 percent protein equivalent than did those ewes fed the basal ration containing approximately 10 percent protein without urea. This experiment did not include any protein levels between 10 and 14 percent, and urea may have been more efficiently utilized at an intermediate level of protein.

Johnson et al. (1942) used rations high in carbohydrates to test the value of urea in rations of different protein levels. Levels of protein from 10 to 14 percent were obtained by adding urea, soybean meal, or casein to a 6.0 percent protein basal ration. Protein levels of 15 to 17 percent were also used in rations which contained urea or a combination of urea and soybean meal. Urea nitrogen supplied from 40 to 65 percent of the total nitrogen intake. Nitrogen from urea seemed to be as well utilized as that of soybean meal, but it was not equal to the nitrogen of casein. Urea prompted greater nitrogen retention of lambs on rations containing up to 12 percent protein, but a further increase in retention was noted when the true protein content of the rations was raised. True or preformed protein of high quality was thus thought to play a necessary part in meeting the protein requirements of growing lambs, since the conversion of urea nitrogen in the paunch did not seem to proceed at a sufficient rate to meet the requirements of the lambs.

McNaught and Smith (1947) pointed out that when protein of low solubility was fed in rations, the production of ammonia from these rations was small, resulting in more favorable conditions for the utilization of urea nitrogen. It would seem that, on a competitive basis, nitrogen from feed protein is more readily accepted for conversion into bacterial protein than is the nitrogen from urea. The suggestion was presented that excessive amounts of readily available or highly soluble forms of protein appeared to limit the production of urea protein by the microorganisms.

Burroughs et al. (1951), from in vitro studies, reported that urea utilization was greatest in the absence of other nitrogenous materials and that high-quality proteins permitted greater utilization of the nitrogen from urea than did low-quality proteins. Casein, zein, gelatin, fish meal, soybean meal, linseed meal, and cottonseed meal were the principal sources of protein tested. It was thought that the microorganisms of the rumen have a definite requirement for ammonia derived from simple nitrogenous substances such as urea. The ammonia-producing feature of proteins appeared to be the chief factor interfering with the utilization of urea. This work would indicate that a considerable portion of the protein utilized by ruminants is of microorganismal origin derived from ammonia and non-protein materials.

Harris *et al.* (1943) used metabolism trials to test the effects of urea in rations for steers. Biological value of urea was found to be 34 percent while that for soybean meal was over 60 percent. This emphasizes the importance of considering biological value as well as the digestibility of protein in rations containing urea.

Briggs *et al.* (1948) reported that urea nitrogen was highly digestible when measured by its decreasing concentration in the rumen, but that lambs were apparently less efficient in its utilization than for nitrogen derived from conventional forms of protein. Storage of nitrogen in the animal body decreased when urea formed more than 50 percent of the total nitrogen of the rations. Lower levels of urea, 4.0 percent to supply 25 percent of the total nitrogen, promoted digestibility of rations and nitrogen storage by lambs to about the same degree as cottonseed meal.

Belasco (1954) compared urea nitrogen with that of soybean meal, linseed meal, cottonseed meal, and corn gluten meal in *in vitro* studies. Urea as a sole source of nitrogen showed higher levels of cellulose digestion than did the protein meals. However, starch had been added to the urea rations to compensate for the nitrogen-free extract fraction of the protein meals used in comparison with urea, and its influence upon cellulytic digestibility may have played a signifiant part in the results.

When urea was used in combination with the protein meals, in 1:1 nitrogen equivalent mixtures, the amount of urea nitrogen utilized was consistently greater than when urea was fed alone. This increase in urea utilization was paralleled by an increase in the digestibility of cellulose, thus improving the efficiency by which rations high in roughage were digested.

The amount and source of energy supplied by the ration seems to play an important part in the utilization of urea. Pierce (1951) and Belasco (1955) have demonstrated that relatively small amounts of starch will increase the efficiency by which urea is utilized. Mills et al. (1942) suggested that the action of starch on urea utilization was that of an energy supplier to the microorganisms, enabling them to build new protoplasm in which nitrogen from urea is incorporated. McDonald (1952) reported starch to be an energy-yielder to help facilitate the utilisation of ammonia by the microorganisms.

Arias et al. (1951) also reported the effect of amounts and sources of energy on the utilization of urea. Cellulose, dextrose, corn cobs, molasses, sucrose, and corn starch were the principal factors tested in the in vitro studies. Results indicated that small amounts of readily available carbohydrates aided cellulose digestion, which in turn increased the utilization of urea. On the other hand, large amounts of starch inhibited cellulytic digestion.

The use of sugars and molasses as energy supplements to rations containing urea has not resulted in consistent findings. Mills et al. (1944) reported a decided increase in urea utilization with the addition of starch to rations for heifer calves, but that corn molasses and cane molasses were inferior carbohydrates for the stimulation of protein synthesis from urea.

It was also believed that small amounts of insoluble, fermentable carbohydrates or insoluble protein are necessary prerequisites in rations for maximum utilization of urea nitrogen. Arias *et al.* (1951) reported beneficial effects upon cellulose digestion when sugars were added with urea to *in vitro* rumen flasks. Culbertson *et al.* (1950) reported that molasses had no beneficial effect upon urea utilization after the first few weeks in rations for fattening yearling steers.

Nitrogen balance and digestibility trials with steers were conducted by Bell *et al.* (1951). Yellow corn, sweet potatoes, milo, barley, cane molasses, and combinations of corn and molasses were the various sources of carbohydrates used in the formulation of the rations. Rations of about 8.0 percent protein consisting of prairie hay, protein supplements, and the different sources of carbohydrates were supplemented with urea to give 11.0 percent protein equivalent. In these trials, urea had little or no effect upon the digestibility of nutrients other than protein. Nitrogen retention was improved significantly when urea was added to the basal ration, with a greater improvement noted when it was added with corn than when added with cane molasses.

The work as reviewed herein seems to justify the use of urea as a partial substitute for dietary protein, although the limits of its addition have not been clearly set forth for all classes of ruminants in past studies. In view of these conflicting results on the utilization of urea by ruminants, further work considering its value and action within the host seems justifiable. Since the amount and source of energy in rations plays an important part in urea utilization, the effect of lard as used in the experiment reported in this thesis may reveal an important effect upon the use of urea in high-energy rations containing added fats and oils. This does not appear to have been studied up to the present time.

in growing lambs than the other meals tested; but the differences were small and nonsignificant, resulting in the same relative efficiency being given to soybean and linseed meals in rations for lambs.

Willman et al. (1946) reported that lambs fed linseed meal as a protein supplement to rations consisting of corn and corn silage were much easier to keep on feed than were lambs fed soybean meal. A higher percentage of roughage offered was consumed, although there was no difference in the average rate of gain between the groups. The net value of the meals appeared to be the same when used as supplements to make up 10 and 11 percent protein rations.

Trials have also been conducted to measure the effect of processing upon the utilization of the common oil meals being used in ruminant feeds. Miller and Morrison (1946) indicated there was no apparent difference in the value for sheep of oil meals made by the hydraulic, expeller, or solvent processes; and that heat treatment of soybean meal resulted in no appreciable improvement in the protein content of the meal for use in lamb rations. They did suggest, however, that the difference in fat content in the meals was apparently more marked in its effect than the digestibility of protein alone.

These and other experiments indicate that soybean and linseed meals have about the same relative value as protein supplements to low protein rations for sheep. However, it was thought that the type of protein supplement might have some effect on the results obtained with the addition of lard and urea, and thus the two kinds of high-protein supplements were included in the study of the problem as presented herein.

METHODS OF PROCEDURE

The experiment reported herein was conducted during the spring and summer of 1955. It was designed to determine the effect of added fat and urea on ration digestibility and nitrogen balance using sheep as the experimental animals. Two basal rations were fed. Soybean meal was the high-protein ingredient used in one and linseed meal in the other. Open kettle-rendered lard was the source of fat. Lard and urea were added alone and in combination to each basal ration. Of particular interest in this experiment was what effect the added lard would have on the utilization of urea.

Twelve wether feeder lambs, showing a predominance of Rambouillet breeding, were used in the experiment. These animals were college stock obtained from the Antelope Range Station during October of 1954, and they averaged approximately 65 pounds upon arrival at Brookings. The animals were housed in a basement experimental room until completion of the experiment. After arrival, they were put on a ration composed of prairie hay similar to that fed in the experimental rations and sufficient concentrate to provide a ration slightly in excess of maintenance until March 15, 1955. During this period, the lambs were weighed periodically to check the growth of the lambs. On March 15, the lambs were allotted to the treatments and the trials begun.

The roughage used in the experiment was a late-cut prairie hay, predominately western wheatgrass. This hay was harvested after frost during the month of October 1953 near Midland, South Dakota, and was stored in a closed loft in the experimental building. The hay was chopped before being given to the animals to reduce sorting of the roughage and to make weighing and feeding easier. Concentrate mixtures containing approximately 19 percent protein were fed with the hay at a rate to give a protein percentage of about 11.5 in the total ration as fed. The prairie hay comprised approximately 50 percent of the ration on a dry basis. It was used in this experiment to provide a roughage low in protein that was suitable for testing the various protein supplements. The protein content of the hay varied from 4.42 to 5.12 percent during different periods of the experiment.

The animals were fed rations of the same protein content to insure as little variation in this nutrient as possible. The object was to determine the effect of urea, lard, and a combination of urea and lard on the nitrogen balance and digestibility of rations containing soybean meal or linseed meal. The protein content of all rations was calculated at 11.5 percent, although the rations consumed varied from 11.0 to 12.3 percent protein on a dry basis. This was due to fluctuations in the protein content of the late-cut prairie hay between periods, moisture content of the rations as fed, and to some feed refusal.

Soybean meal and linseed meal used in the trials were of solvent process, containing approximately 44 percent and 36 percent protein, respectively. The fat added to the rations was kettle-rendered lard, which was added to the concentrate portion of the ration at the time of mixing. The rations were mixed in a tank type mixer at the beginning of every preliminary period. The lard was melted in a force-draft oven at 70° C and added to the concentrate mixture while the mixer was running. This produced rations of uniform mixing, and no tendency toward lumpiness was noted. The lard was stabilized with butylated hydroxy-anisole, a commercial antioxidant, before being added to the concentrate portion of the rations. The amounts of the various ingredients used in the concentrate portion of the rations are given in Table 1.

Table 1. Kind and Amount of Ingredients Used in the Concentrate Mixtures Fed in the Digestion Trials (Percent).

	Concentrate Mixtures							
	Soybean Rations				Linseed Rations			
	1	2	3	4	5	6	7	8
Ingredients	Basal	Urea	Lard	Urea+Lard	Basal	Urea	Lard	Urea+Lard
Ground shelled corn	79.2	89.1	67.6	77.5	74.1	87.4	61.6	75.5
Soybean meal	18.1	6.2	20.6	9.0				
Linseed meal					23.2	8.2	27.0	11.2
Urea		1.8		1.8		1.7		1.8
Lard			8.8	8.8			8.7	8.8
Bone meal	1.0	1.2	1.0	1.2	.4	1.0	.4	1.0
Limestone					.4		.4	
Trace-mineralized salt	1.7	1.7	2.0	1.9	1.9	1.7	1.9	1.9

* Each ration supplemented with 20 grams "Nopcay" Type III vitamin A to furnish 2,000 U. S. P. units of vitamin A per pound of concentrate feed.

** Each ration supplemented with 2.25 grams Dawe's Dry D_2 to furnish 200 U. S. P. units of vitamin D per pound of concentrate feed.

A total of four metabolism trials were conducted. Each trial consisted of a preliminary period of approximately 30 days and the collection period of seven days. The long preliminary period was used to facilitate transfer of rations between lambs from one period to another so that no carryover effect would be measured. At the end of each preliminary period, the lambs were placed in metabolism crates similar to those reported by DuBose (1954). A seven-day interval between the preliminary period and the collection period was provided to accustom the lambs to the metabolism crates. At the end of this interval, the lambs were weighed and the actual collection begun.

The lambs were fed twice daily throughout the experiment with equal amounts of feed being offered in the morning and afternoon. Feeding schedules were so arranged that feeding was done as soon after 8:00 A. M. and before 5:00 P. M. as was possible. During the preliminary periods, all animals were fastened for about three hours at each feeding to allow time for complete consumption of the feed. The concentrate portion of the rations was fed on top of the roughage to induce consumption of the hay, which was relatively dusty. Between feedings, the lambs were allowed to exercise in a pen on a well drained floor with ground corn cobs as bedding. Water was available to the lambs at all times except during the time allotted for the consumption of the ration.

The rate of feeding to each lamb was 500 grams of feed twice daily per each 100 pounds of body weight, based upon the initial weight of the animals taken just prior to the start of the experiment. The rate of feeding was increased 5.0 percent of the total ration, dry basis, at the beginning of each successive period. This was done to compensate for the increase in weight among the animals during the periods and to eliminate favoritism toward those lambs whose rate of gain was high for the preceding period. Weights of the animals were taken at the beginning of each preliminary and collection period. Some of these weights are shown in Table 2. All the lambs were gaining weight during the experiment.

Table 2. Weight of Lambs at the End of Each Collection Period (Pounds).

	Digestion Period and Date of Weighing				
Lamb No.	Initial March 15	1 May 16	2 June 28	3 August 12	4 Sept. 28
1	78.5	88.0	96.0	103.0	108.0
2	91.0	92.0	102.0	103.0	114.0
3	78.0	82.0	90.0	92.0	95.0
4	96.5	103.0	108.0	115.0	120.0
5	81.0	89.0	93.0	100.0	107.0
6	77.5	81.0	85.0	89.0	91.0
7	82.0	88.0	92.0	100.0	108.0
8	89.0	92.0	100.0	108.0	111.0
9	78.0	84.0	90.0	97.0	103.0
10	91.0	94.0	102.0	109.0	117.0
11	82.5	86.0	95.0	101.0	104.0
12	70.5	77.0	80.0	86.0	94.0

Consumption of the concentrate portion of the ration during the trials appeared essentially complete. However, hay was refused by some animals in all periods. Hay refused during the collection periods was placed in individual containers until the end of the period. This hay was then dried at 100° C for four days in a force-draft oven and then weighed to determine the weight of orts on a dry basis. Samples of the orts were then finely ground in a Wiley mill and saved for chemical analyses for moisture, protein, ash, ether extract, crude fiber, and nitrogen-free extract. Three samples of the hay and each concentrate were taken on separate days and treated in a similar manner as the orts. Complete records of feed offered and refused were kept during the entire course of the investigation.

The total collection method was used in determining the nutrients excreted in both the urine and the feces. Feces were collected in canvas bags attached by harness to the animals. The bags were emptied once each day and the total weight of the feces recorded. A 3.0 percent sample of feces from each lamb was taken at each weighing and frozen in a glass jar until the end of each period. The samples were subsequently removed, thawed, ground in a meat grinder, and representative portions were sent to the Experiment Station Biochemistry Department for analyses.

Urine was collected in large-mouth, glass containers fitted with wide funnels. These containers were placed underneath the metabolism crates to collect the urine. The urine was preserved with a 50 percent sulfuric acid solution, 50 ml. being added to the urine bottles each day. Total volume of the urine was recorded each day, and a 10 percent volume sample was saved from each animal and kept refrigerated until the end of each period. Samples were then submitted to the Experiment Station

Biochemistry Department for analysis of nitrogen. Coefficients of apparent digestibility for crude protein, ether extract, crude fiber, nitrogen-free extract, dry matter, and organic matter, and nitrogen balance were then calculated in the conventional ways.

The trials were set up factorially so that the interactions between treatments could be measured, as well as the main effects. Soybean meal and linseed meal served as whole plots with urea and lard as split plots in the design. A total of eight rations were offered during the experiment. Each ration was offered twice, with rations 2, 3, 5, and 8 being offered in periods 1 and 3, and rations 1, 4, 6, and 7 being offered in periods 2 and 4. Each of the four rations offered each period was fed to three animals, making a total of six lambs receiving the same treatment during the experiment. The only restriction placed upon the design of the experiment was that no lamb would receive the same treatment twice throughout the trials. The design of the experiment and the rations received by each lamb are given in Table 3.

Table 3. Design of the Digestion Trials.

Digestion Periods	Soybean Rations		Linseed Rations	
1	Soybean-Urea	Soybean-Lard	Linseed Basal	Linseed-Urea-Lard
Lamb numbers	6, 8, 11	4, 5, 12	3, 7, 10	1, 2, 9
2	Soybean Basal	Soybean-Urea-Lard	Linseed-Urea	Linseed-Lard
Lamb numbers	2, 3, 11	5, 8, 9	4, 6, 7	1, 10, 12
3	Soybean-Urea	Soybean-Lard	Linseed Basal	Linseed-Urea-Lard
Lamb numbers	2, 7, 10	1, 3, 9	6, 8, 11	4, 5, 12
4	Soybean Basal	Soybean-Urea-Lard	Linseed-Urea	Linseed-Lard
Lamb numbers	5, 8, 12	7, 10, 11	1, 3, 9	2, 4, 6

RESULTS AND DISCUSSION

Summaries of the feed consumption and coefficients of apparent digestibility by lambs on each ration are presented in Appendix Tables I-VIII. Results of apparent digestibility for each nutrient together with the statistical analysis for that nutrient will be presented separately herein. Analysis of variance was the statistical method employed to determine significance of the results. The effects of periods and proteins were tested for statistical significance with error A, which was the periods x protein interaction. All other effects and interactions were tested by error B, which was the remainder. In the statistical analysis, the term protein has been used to indicate the linseed meal and soybean meal treatments.

Feed Consumption and Weight Gains

The average feed consumption and weight gains of lambs fed late-cut prairie hay and various concentrates are presented in Tables 4 and 5. The variation in average weight for the groups on the various treatments was due primarily to differences in initial weight of the animals, and the fact that each lamb did not receive all treatments. The average daily gain for each treatment group showed uniformity between the groups fed rations containing lard. Their average daily gain was from 0.12 to 0.13 pound while those groups fed rations without lard gained slightly less. All gains were rather small and include the time the lambs were in the metabolism crates. While the differences in rate of gain are nonsignificant in these trials, the results might indicate that under feed-lot conditions, the effect of lard might promote a significant increase in average daily gain.

Table 4. Average Feed Consumption and Weight Gains of Lambs Fed Late-cut Prairie Hay and Various Soybean Concentrates.

	Soybean Basal	Soybean Urea	Soybean Lard	Soybean Urea-Lard
Number of lambs	6	5	5	6
Av. initial weight, lbs.	92.3	88.6	86.8	95.8
Av. daily gain, lbs.	0.16	0.10	0.13	0.13
Av. daily dry matter fed, gms.	934	888	850	948
Av. daily rations consumed, gms.				
Dry matter	908	877	806	901
Crude protein	108	97	96	108
Ether extract	25	32	67	77
Nitrogen-free extract	532	526	439	478
Crude fiber	171	156	138	165
Organic matter	834	811	740	828
Protein in ration consumed, %	11.9	11.1	11.9	11.9

Table 5. Average Feed Consumption and Weight Gains of Lambs Fed Late-cut Prairie Hay and Various Linseed Concentrates.

	Linseed Basal	Linseed Urea	Linseed Lard	Linseed Urea-Lard
Number of lambs	5	5	4	6
Av. initial weight, lbs.	89.2	94.4	93.5	88.1
Av. daily gain, lbs.	0.10	0.11	0.13	0.12
Av. daily dry matter fed, gms.	888	926	932	875
Av. daily ration consumed, gms.				
Dry matter	885	883	897	821
Crude protein	106	102	111	101
Ether extract	26	24	75	75
Nitrogen-free extract	526	521	460	437
Crude fiber	162	165	173	143
Organic matter	815	795	819	756
Protein in ration consumed, %	12.0	11.6	12.4	12.3

Feed consumption during the first period of collection was essentially complete for all of the lambs. In the succeeding periods, however, some lambs began to refuse feed. Most of the trouble was encountered with lambs 2, 3, and 6 which refused a large amount of feed in all periods after the first one. For this reason, the date obtained from these lambs during the periods of high feed refusal were omitted, resulting in unequal number of lambs between the different treatments.

Space was not available to permit the inclusion of all treatments in each period. In the design of the experiment, the overall effects of soybean meal, linseed meal, urea, and lard were to be measured with 24 lambs each. This number was thought to be sufficient even with the above limitation and also the fact that each lamb did not receive all treatments.

Excluding the lambs mentioned above resulted in the following number of lambs in each group: basal, 11; urea, 10; lard, 9; and urea-lard, 12. The design of the experiment did not permit one to determine if the lard rations were unpalatable to certain lambs or if these lambs were not good experimental animals for use in metabolism crates. The data in Tables 4 and 5 do show that feed consumption by the remaining lambs was quite similar in the various groups. Therefore, one cannot conclude that the rations with urea or lard were unpalatable at the levels used in these experiments. The lambs were fed a given quantity of feed per unit of body weight which accounted for the differences in amount of feed offered.

Digestibility of Protein

Coefficients of apparent digestibility of protein by lambs fed late-cut prairie hay and various concentrates are presented in Table 6. The statistical analysis of the data is shown in Table 7.

The apparent digestibility of protein by lambs receiving linseed meal rations was slightly higher than for lambs receiving soybean meal rations, with the greatest differences occurring between the basal groups. However, this effect was statistically nonsignificant and indicated that the two protein supplements were about of equal value as measured by the apparent digestibility of protein. This agrees with other work cited previously.

Digestibility of protein in both the soybean and linseed rations were slightly lower when urea was present. This was true in the presence or absence of lard. However, this reduction was quite small and was not statistically significant. Embry and Gastler (1955) reported there were no differences in digestibility of protein in high-roughage rations for calves and lambs when corn and about 4 percent urea was used to replace an equivalent amount of protein and total digestible nutrients from soybean meal. On the other hand, Reid (1953), after a review of the literature on urea feeding, concluded that the value of urea in fattening rations for cattle and sheep was less well established than for wintering rations for these species and for feeding dairy cattle. The rations used in the experiment reported herein were fattening-type rations for lambs. The results indicate small, if any, influence of urea on apparent digestibility of the protein in these rations.

Table 6. Coefficients of Apparent Digestibility of Protein by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

	1 Basal	2 Urea	3 Lard	4 Urea-Lard
	54.8	57.5	67.3	63.8
	63.2	55.2	69.9	65.6
	56.3	61.4	62.2	62.3
	63.9	60.9	62.4	63.2
	58.3	60.9	69.0	64.6
	62.7			70.5
Av.	59.9	59.2	66.2	65.0

Linseed rations.

	5 Basal	6 Urea	7 Lard	8 Urea-Lard
	65.5	62.4	65.7	69.4
	68.9	63.4	69.6	68.2
	59.2	56.9	67.5	64.1
	62.7	61.3	65.5	60.7
	61.9	62.0		69.9
				62.0
Av.	63.6	61.2	67.1	65.7

Averages for both rations.

Basal	Urea	Lard	Urea-Lard
61.8	60.2	66.7	65.3

Table 7. Analysis of Variance of Digestion Coefficients for Crude Protein.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	35.6375	3.31
Protein	1	34.3728	3.19
Error A (Periods x Protein)	3	10.7630	
Urea	1	6.8904	.20
Fat	1	258.3168	7.53*
Protein x Urea	1	5.0106	.15
Protein x Fat	1	11.8885	.35
Periods x Protein x Split Plot	12	2.3148	.07
Error B (Remainder)	18	34.3109	

* Significant at the 5% level.

Coefficients of apparent digestibility of protein by lambs fed the rations containing lard, with or without urea, seemed to be clearly superior to the other rations. Average digestibility figures of the rations containing lard were 66.7 and 65.3 percent as compared to 60.2 and 61.8 percent for the basal and urea rations, respectively. This effect is in agreement with other work cited in the Review of Literature.

Apparent digestibility of protein was only slightly less in the urea-lard rations as compared with those containing lard alone. This slight depression appeared to be due to the effect of urea, since the same depression occurred in rations which did not contain lard.

A primary object of this experiment was to determine the effect of added fat on the utilization of urea. Reference has been made in the Review of Literature to the difference between starch and sugar in urea utilization, but the effect of fat appears not to have been studied. This is an important problem, since fat and urea are sometimes used together in commercial feeds. These results indicate that the improvement in protein digestibility of the urea-lard rations over the urea rations was due to the effect of the lard. The lard improved apparent digestibility of protein in rations with and without urea to about the same degree, indicating that lard had no specific effect on the digestibility of urea nitrogen.

Digestibility of Ether Extract

Digestibility of ether extract in rations containing high levels of fat will have an important influence on the energy value of the rations. Various kinds of waste fats appear to vary widely in their digestibility. The coefficients obtained in this experiment for apparent digestibility of ether extract by the lambs are presented in Table 8. The statistical analysis of ether extract digestibility by lambs fed late-cut prairie hay and various concentrates is given in Table 9.

A comparison of digestion coefficients obtained with all rations not containing lard revealed a high degree of variability in the digestibility of ether extract. When lard was included in the rations, coefficients of digestibility were found to be more uniform, and there was no significant difference between the linseed and soybean rations.

The effect of urea upon the digestibility of ether extract was found to be dependent upon the type of protein supplement used. Urea appeared to increase the digestibility of ether extract when used in combination with soybean meal, and to depress the digestibility when used with linseed meal. This interaction was significant at the 5 percent level. The overall effect of urea showed a small gain over the control group, but this was nonsignificant. A slight depression in digestibility was noted when urea and lard were fed together over that when lard was fed alone, but again this was not significant.

The added lard was highly digestible by the lambs, and digestibility of ether extract of rations containing lard was increased by more than 40 percentage units over those rations not receiving lard. This increase was highly significant. Considering the amount of ether extract consumed multiplied by the percent digestibility of each ration, lambs receiving lard rations apparently digested approximately 40 grams more ether extract per day than did those lambs on the basal and urea rations. This would mean a higher caloric intake for these animals and would tend to explain the slightly higher average daily gains in weight that occurred within these groups even though feed consumption was slightly less.

Table 8. Coefficients of Apparent Digestibility of Ether Extract by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

	1 Basal	2 Urea	3 Lard	4 Urea-Lard
	13.7	27.6	74.8	56.5
	40.9	56.2	70.0	73.7
	21.6	29.8	65.3	64.7
	28.5	52.1	76.6	64.7
	25.2	50.0	72.0	75.6
	33.1			79.9
Av.	27.2	43.1	71.7	69.5

Linseed rations.

	5 Basal	6 Urea	7 Lard	8 Urea-Lard
	34.0	14.6	71.8	66.8
	32.8	20.5	81.5	75.6
	40.2	16.7	72.4	74.9
	10.6	22.3	73.2	75.5
	54.0	30.8		77.9
				74.2
Av.	34.3	21.0	74.7	74.2

Averages of both rations.

Basal	Urea	Lard	Urea-Lard
30.8	32.1	73.2	71.9

Table 9. Analysis of Variance of Digestion Coefficients for Ether Extract.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	664.7339	9.06
Protein	1	22.5248	.31
Error A (Periods x Protein)	3	73.3976	
Urea	1	180.8019	2.58
Fat	1	17789.7636	253.75**
Protein x Urea	1	406.8596	5.80*
Protein x Fat	1	297.3785	4.24
Periods x Protein x Split Plot	12	----	----
Error B (Remainder)	18	70.1085	

* Significant at the 5% level.
** Significant at the 1% level.

Digestion coefficients for ether extract were slightly higher for the linseed than for the soybean meal rations when lard was present. Averages of soybean and linseed rations not containing lard were 35.1 and 27.6 percent, respectively. In the presence of lard, corresponding values were 70.3 and 74.4 percent, respectively. However, this interaction was not significant, although variation between the protein supplements was apparent.

These results show that the lard was highly digestible; and when added at the rate of about 5 percent to the total ration, considerably higher digestion coefficients for ether extract were obtained. The addition of highly digestible fat at this level would result in a ration of greater energy value unless depression in digestibility of other nutrients occurred and was great enough to offset this increase. A slight improvement in digestibility of protein following the addition of lard has been reported in the previous section.

Digestibility of Crude Fiber

Coefficients of apparent digestibility of crude fiber by lambs fed late-cut prairie hay and various concentrates are given in Table 10. The statistical analysis of the data is presented in Table 11.

Average digestion coefficients for lambs on the linseed and soybean basal rations appeared to be quite similar and there was no significant difference between the two rations due to the type of protein supplement used.

Table 10. Coefficients of Apparent Digestibility of Crude Fiber by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

	1 Basal	2 Urea	3 Lard	4 Urea-Lard
	63.2	37.7	48.3	58.6
	63.7	57.4	49.6	44.6
	52.8	49.6	49.2	51.7
	45.3	52.2	47.0	49.7
	57.1	53.7	51.9	44.5
	58.1			49.5
Av.	56.7	50.1	49.2	49.8

Linseed rations.

	5 Basal	6 Urea	7 Lard	8 Urea-Lard
	56.9	53.6	50.8	47.9
	57.6	59.1	47.3	44.0
	52.7	54.4	47.8	38.5
	54.2	56.3	50.8	46.8
	50.3	54.0		50.6
				48.8
Av.	54.3	55.5	49.2	46.1

Averages for both rations.

Basal	Urea	Lard	Urea-Lard
55.5	52.8	49.2	48.0

Table 11. Analysis of Variance of Digestion Coefficients for Crude Fiber.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	87.2291	2.09
Protein	1	2.5346	.06
Error A (Periods x Protein)	3	41.7375	
Urea	1	70.7102	2.92
Fat	1	356.1842	14.71**
Protein x Urea	1	6.4792	.27
Protein x Fat	1	29.9289	1.24
Periods x Protein x Split Plot	12	1.7300	.07
Error B (Remainder)	18	24.2077	

** Significant at the 1% level.

The overall treatment effect of urea upon the digestibility of crude fiber was nonsignificant, although there appeared to be some depression when urea was added with soybean meal. Embry and Gastler (1955) reported similar digestion coefficients for crude fiber with rations containing soybean meal and soybean meal with 4.0 percent urea.

The addition of lard to the rations produced a highly significant effect upon the digestibility of crude fiber. Lard depressed crude fiber digestibility by approximately 6.0 percentage units when compared with the basal rations. The average digestibility for the lard and urea-lard rations was about the same. There was some difference between rations with soybean and linseed meal, but this was not statistically significant. The depression of crude fiber digestibility by adding fats to rations has also been reported by others (Brooks et al., 1953; Brooks et al., 1954; and Erwin et al., 1955). Thus the use of added fats to rations for ruminants becomes a matter of practical concern particularly with high-roughage rations, since the digestibility of crude fiber is more important with rations high in roughage than with those high in concentrates. The levels of fat used in ruminant rations will also be an important consideration, as shown by the work of Swift et al. (1947), Kammlade and Butler (1954), Hale and King (1955), Mason et al. (1955), and Kercher et al. (1956).

Digestibility of Nitrogen-free Extract

The influence of added fat upon digestibility of the nitrogen-free extract portion of the ration is an important consideration since it may affect the energy value of the ration. Coefficients of apparent digestibility for nitrogen-free extract by the lambs are presented in Table 12. The statistical analysis of the data is given in Table 13.

Table 12. Coefficients of Apparent Digestibility of Nitrogen-free Extract by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

	1 Basal	2 Urea	3 Lard	4 Urea+Lard
	75.0	71.6	68.6	71.2
	73.7	72.8	72.5	57.3
	62.4	71.5	68.4	67.4
	66.6	66.1	68.0	70.1
	74.2	73.0	67.7	63.7
	70.4			67.1
Av.	70.4	71.0	68.4	66.1

Linseed rations.

	5 Basal	6 Urea	7 Lard	8 Urea+Lard
	70.7	65.4	65.3	67.1
	73.2	73.6	67.7	67.7
	68.2	72.3	70.0	68.9
	74.6	73.3	69.3	64.8
	68.1	67.1		69.4
				61.6
Av.	71.0	70.3	68.1	66.6

Averages for both rations.

Basal	Urea	Lard	Urea+Lard
70.7	70.7	68.3	66.4

Table 13. Analysis of Variance of Digestion Coefficients for Nitrogen-free Extract.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	85.1831	12.02*
Protein	1	.0596	.01
Error A (Periods x Protein)	3	7.0856	
Urea	1	19.1392	1.87
Fat	1	134.1787	13.12**
Protein x Urea	1	.5730	.06
Protein x Fat	1	.0554	.01
Periods x Protein x Split Plot	12	.7943	.08
Error B (Remainder)	18	10.2300	

* Significant at the 5% level.
** Significant at the 1% level.

Coefficients of digestibility of nitrogen-free extract between the lambs fed soybean meal and those fed linseed meal were similar and quite high values were obtained. Urea also did not affect the digestibility of nitrogen-free extract. Averages of the overall treatment effects in comparing the basal and urea groups were 70.9 and 70.7 percent, respectively.

Lard significantly depressed the digestibility of nitrogen-free extract. This decrease in digestibility was rather small as compared with the other significant effects within the experiment, but was found to be significant at the 1.0 percent level. Average digestion coefficients were 68.3 and 66.4 percent for lard and urea-lard rations, respectively. These averages were 2.5 and 4.4 percentage units under those obtained from rations not containing lard. It appears that lard decreased the digestibility of nitrogen-free extract in both types of protein rations to about the same extent. Although the urea-lard rations gave lower averages of digestibility than did those rations containing lard alone, this effect was nonsignificant.

Digestibility of Organic Matter and Total Digestible Nutrients

The rations containing linseed and soybean meal were quite similar when measured by digestibility of the various nutrients. Urea did not have any significant effect on digestibility of the rations. On the other hand, adding fat at the rate of 5 percent of the total ration increased apparent digestibility of crude protein and ether extract, but decreased digestibility of crude fiber and nitrogen-free extract. The net value of the added lard will depend largely upon the digestibility of the total organic matter and the total digestible nutrients in the ration. Coefficients of apparent digestibility of organic matter by lambs fed late-cut prairie hay and various concentrates are presented in Table 14. The statistical analysis of the data is shown in Table 15. Total digestible nutrients have been calculated and are presented in Table 16.

Only very small differences existed in the comparison of the digestibility of organic matter between rations and none of the differences were statistically significant. This would be expected in view of the previously presented results except in the case of rations containing lard. In the rations with lard, apparently the increase in digestibility of crude protein and ether extract just about balanced the decrease in digestibility of crude fiber and nitrogen-free extract. This resulted in digestible organic matter being nearly equal in the rations with and without lard.

There seemed to be no consistent trend in the total digestible nutrients content of the linseed and soybean meal rations, with or without urea and lard. The averages for all rations with linseed meal was about the same as for those with soybean meal. The values for the rations with urea were also quite similar to those without urea.

Added lard resulted in an increase in total digestible nutrients over other rations not containing lard. Since high-energy products such as lard contributes approximately two and one-fourth times the energy value of protein or carbohydrates, this effect was considered to be normal in view of the fact that total digestible organic matter was essentially the same in all rations.

Table 14. Coefficients of Apparent Digestibility of Organic Matter by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

	1 Basal	2 Urea	3 Lard	4 Urea-Lard
	67.8	62.2	65.0	66.4
	69.4	66.8	68.0	57.5
	58.4	64.7	63.7	63.4
	60.9	62.0	62.4	64.7
	67.3	67.1	65.5	61.1
	65.6			65.6
Av.	64.9	64.6	64.9	63.1

Linseed rations.

	5 Basal	6 Urea	7 Lard	8 Urea-Lard
	66.1	61.6	62.8	63.7
	68.2	67.8	65.1	64.8
	63.0	65.4	65.1	63.2
	66.9	66.9	65.2	61.7
	63.2	62.7		66.8
				60.3
Av.	65.5	64.9	64.6	63.4

Averages for both rations.

Basal	Urea	Lard	Urea-Lard
65.2	64.8	64.8	63.3

Table 15. Analysis of Variance of Digestion Coefficients for Organic Matter.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	33.8438	4.34
Protein	1	.0189	.00
Error A (Periods x Protein)	3	7.7929	
Urea	1	16.7679	2.24
Fat	1	7.2583	.97
Protein x Urea	1	.2305	.03
Protein x Fat	1	.0046	.00
Periods x Protein x Split Plot	12	.8102	.11
Error B (Remainder)	18	7.4896	

Table 16. Total Digestible Nutrients by Lambs Fed Late-cut Prairie Hay and Various Concentrates.

Soybean rations.

1 Basal	2 Urea	3 Lard	4 Urea-Lard
64.5	61.5	70.6	66.7
65.1	64.5	67.6	64.6
62.6	61.1	66.6	65.9
54.4	64.1	74.0	61.1
57.0	58.6	64.8	64.6
61.4			69.8
Av. 60.8	62.0	68.7	65.5

Linseed rations.

5 Basal	6 Urea	7 Lard	8 Urea-Lard
63.6	63.3	64.8	66.5
63.5	62.4	67.1	69.5
62.1	56.4	68.3	70.7
58.9	59.7	62.7	66.4
59.6	58.4		64.4
			63.1
Av. 61.5	60.0	65.7	66.8

Averages for both rations.

Basal	Urea	Lard	Urea-Lard
61.2	61.0	67.2	66.2

The results of the experiment show that rations containing linseed meal or soybean meal were about equal for fattening lambs when measured by digestible organic matter and total digestible nutrients. Substituting urea and corn for part of the high-protein ingredient did not significantly affect the digestibility of the rations. Apparently urea was utilized to about the same degree with either linseed or soybean meal.

Adding lard did not affect the digestibility of organic matter, but the added fat gave the rations a higher value in total digestible nutrients. The practical value of adding fats to rations for fattening lambs will depend largely upon the comparative price with grains as a source of energy. The increase in digestibility of protein and improvement in mixing and handling qualities of the feed may be given some extra value.

Nitrogen Balance Trials

In order to obtain more information concerning the effect of lard and of linseed meal and soybean meal on the utilization of urea nitrogen, nitrogen balance trials were conducted in conjunction with the digestion trials. The data for the nitrogen balance trials are presented in Tables 17 and 18 and the statistical analysis is shown in Table 19. Data for lambs during periods of high feed refusal (discussed previously) were omitted from this phase of the experiment also.

Table 17. Nitrogen Metabolism Data for the Individual Lambs on Soybean Rations.

Lamb No.	Ration Received	Initial Body Weight Lbs.	Total Gain in Weight for 7 days Lbs.	Dry Feed Consumed Daily Gms.	Nitrogen Metabolism per Day: Intake Gms.	Feces Gms.	Urine Gms.	Balance Gms.	Nitrogen Consumed Retained %
2	Basal	102.0	-2.0	920.2	16.4	7.4	8.4	.6	3.9
3	1	90.0	0	847.2	15.0	5.5	8.0	1.5	10.1
5	1	106.0	1.5	965.9	19.5	8.5	7.9	3.1	15.7
8	1	113.5	-3.0	977.3	20.3	7.3	8.7	4.3	21.3
11	1	93.0	-1.0	896.3	15.9	6.6	7.3	2.0	12.0
12	1	92.0	2.5	842.1	17.0	6.3	7.0	3.7	21.4
	Average	99.8	-0.3	908.2	17.4	6.9	7.9	2.6	14.1
6	[illegible]	80.0	1.0	742.8	13.2	5.6	7.0	.6	4.7
7	2	98.0	2.0	917.6	16.4	7.4	7.9	1.1	7.3
8	2	92.0	0	896.7	15.7	6.0	7.3	2.4	15.0
10	2	107.0	2.0	1001.1	17.9	7.0	8.6	2.3	13.1
11	2	85.0	1.0	827.8	14.4	5.6	5.7	3.1	21.5
	Average	92.4	1.2	877.2	15.5	6.3	7.3	1.9	12.3
1	Lard	98.0	5.0	837.5	16.0	5.2	7.5	3.3	20.5
4	3	98.0	5.0	893.6	17.3	5.2	9.2	2.9	16.9
5	3	87.0	2.0	822.9	15.2	5.8	7.8	1.6	11.3
9	3	97.0	0	762.1	15.3	5.7	7.7	1.9	11.7
12	3	74.0	3.0	712.6	13.2	4.1	7.0	2.1	15.7
	Average	90.8	3.0	805.7	15.4	5.2	7.8	2.4	15.2
5	Urea - Lard	95.0	-2.0	836.1	15.7	5.7	8.7	1.3	8.4
7	4	105.5	2.5	966.3	18.5	6.4	7.4	4.7	25.7
8	4	100.0	0	952.2	17.4	6.6	7.8	3.0	17.1
9	4	91.0	-1.0	800.1	14.8	5.4	7.1	2.3	15.1
10	4	117.5	0	988.1	19.4	6.8	9.9	2.7	13.7
11	4	103.5	1.0	844.8	17.5	5.2	9.0	3.3	19.0
	Average	102.1	0.1	901.3	17.2	5.9	8.3	2.3	16.5

Table 18. Nitrogen Metabolism Data for the Individual Lambs on Linseed Rations.

Lamb No.	Ration Received	Initial Body Weight Lbs.	Total Gain in Weight for 7 days Lbs.	Dry Feed Consumed Daily Gms.	Nitrogen Metabolism per Day: Intake Gms.	Feces Gms.	Urine Gms.	Balance Gms.	Nitrogen Consumed Retained %
3	Basal	81.0	1.0	783.6	15.0	5.2	7.0	2.8	18.8
7	5	85.0	3.0	824.5	15.8	4.9	7.4	3.5	22.1
8	5	107.0	1.0	981.6	18.9	7.7	7.4	3.8	20.2
10	5	90.0	4.0	915.1	17.6	6.5	7.0	4.1	22.9
11	5	101.0	0	920.7	17.8	6.8	6.4	4.6	25.9
	Average	[illegible]	1.8	885.1	17.0	6.2	7.0	3.8	22.0
1	Urea	104.0	4.0	916.4	17.9	6.8	7.7	3.4	19.7
4	6	109.0	-1.0	1043.3	18.1	6.6	10.5	1.0	5.2
6	6	87.0	-2.0	707.8	13.4	5.8	7.4	.2	1.7
7	6	92.0	0	[illegible]	15.4	6.0	8.7	.7	4.7
9	6	102.0	1.0	[illegible]	16.8	6.4	7.2	3.2	19.4
	Average	98.8	0.4	[illegible]	16.3	6.3	[illegible]	1.7	10.1
1	Lard	93.0	1.0	844.9	16.5	5.7	7.3	3.5	21.3
4	7	118.0	2.3	1001.1	20.5	6.2	10.3	4.0	19.3
10	7	100.0	2.0	982.4	19.2	6.2	9.0	4.0	20.6
12	7	81.0	-1.0	769.6	14.9	5.1	7.7	2.1	13.6
	Average	98.5	1.1	897.3	17.8	5.8	8.6	3.4	18.7
1	Urea - Lard	86.0	2.0	778.2	14.8	4.5	6.3	4.0	27.2
2	8	90.0	2.0	747.8	15.4	4.9	8.2	2.3	15.0
4	8	114.0	1.0	945.4	19.2	6.9	9.5	2.8	14.7
5	8	97.0	3.0	902.3	17.4	6.8	7.7	2.9	16.7
9	8	82.0	2.0	774.2	14.9	4.5	6.9	3.5	23.8
12	8	85.0	1.0	778.0	15.0	5.7	7.1	2.2	14.8
	Average	92.3	1.8	821.0	16.1	5.6	7.6	2.9	16.7

Table 19. Analysis of Variance of the Nitrogen Metabolism Data.

Source of Variation	Degrees of Freedom	Mean Square	F Values
Periods	3	143.93	2.84
Protein	1	83.37	1.65
Error A (Protein x Periods)	3	50.61	
Urea	1	70.37	2.29
Fat	1	75.49	2.46
Protein x Urea	1	91.21	2.97
Protein x Fat	1	---	----
Periods x Protein x Split Plot	12	18.97	.62
Error B (Remainder)	18	30.74	

Differences in the average weight of lambs between groups may be explained on the basis of periods in which each treatment was studied. Rations 2, 3, 5, and 8 were offered in periods 1 and 3. The average initial weight of lambs fed these rations would be less than for those fed rations 1, 4, 6, and 7 in periods 2 and 4, since they gained some weight during the long preliminary periods.

Feed-consumption data for the lambs show some differences. The variation was the result of differences in initial weight of the animals, and the subsequent feeding to all animals on a standard basis per unit of body weight. Since the amount of feed fed daily was raised 5 percent with each successive period of the trials, averages of the data from periods 2 and 4 would be slightly higher than for periods 1 and 3. Actual intake of protein was also affected slightly by these factors. However, uniformity between the treatments was considered good.

Weight gains for the lambs during the nitrogen balance trials have been presented in Tables 17 and 18. These data represent the total gain for each lamb over the seven-day collection period. The majority of lambs made some gain, with variation between groups being small. A few of the lambs lost weight during the time they were in the metabolism crates. However, losses in weight were small and not much significance should be attached to these weights, since they represent only a short period of time. Reference is made to the weight gains of lambs in Tables 4 and 5, which are averages for each group of lambs during both the preliminary and collection periods. The data in these tables show that all lambs were gaining in weight during the period they were fed each ration.

The nitrogen metabolism data were corrected for metabolic fecal nitrogen, using the method as presented by Blaxter and Mitchell (1948). Endogenous urinary nitrogen, taken to be 0.035 grams of nitrogen per kilogram of body weight, as given by Embry (1950), was also calculated. Correction for these two fractions gave essentially the same results as presented for the uncorrected data, although balance figures were maintained at a higher level. Therefore, only the uncorrected data are presented.

The daily nitrogen intake by lambs on linseed rations averaged slightly higher than for those lambs on soybean rations. There was uniformity between groups, however, with the lower averages in most cases resulting chiefly from the size of the animals and the periods in which these rations were offered. These factors have been discussed in the previous sections.

Averages of fecal nitrogen excretion per day were very similar for the soybean and linseed rations, with and without urea and lard. Urea nitrogen appeared to have no influence on the amount of fecal nitrogen excreted with either the linseed or soybean rations. Lard, however, appeared to reduce the amount of fecal nitrogen excreted by the lambs. This effect was also noted when urea and lard were fed together, but appeared to be due to the action of lard. Lard resulted in a significant improvement in digestibility of protein but the type of high-protein ingredient and urea had no effect on digestibility of protein. (See section "Digestibility of Protein" for a discussion of this.)

Values for urinary nitrogen excretion showed no consistent trends due to the treatments, but the values were somewhat variable. However, these differences were not evaluated statistically, except as they affected the nitrogen balance.

Averages of nitrogen balance by lambs were consistently higher for linseed than for soybean rations, with the exception of those containing urea alone. The difference in favor of linseed meal was the greatest between the basal groups. The amount of nitrogen excreted in the feces and urine was quite similar for the two high-protein ingredient groups. The slightly greater intake of nitrogen by the lambs fed linseed meal resulted in the higher balance figures which were not statistically significant.

Nitrogen balance was lowest when the rations contained urea without lard. The differences between the urea and other groups was more pronounced with the linseed meal rations. However, individual variation was great and the nitrogen balance for the urea groups was not significantly different from the others.

Lard did not result in any significant change in the nitrogen balance of lambs. Comparison of lambs receiving rations containing lard alone against those receiving the basal rations did not reveal any important differences in nitrogen balance.

Rations containing both urea and lard gave nitrogen balance values similar to those for lard without urea. The percent of consumed nitrogen retained was higher than with the rations containing urea but no lard. This seemed to suggest an improvement in the utilization of urea nitrogen in the presence of lard. However, the improvement was primarily due to a reduction in fecal nitrogen and an improvement in digestibility rather than a change in the utilization of the digested nitrogen.

SUMMARY AND CONCLUSIONS

Nitrogen balance and digestion trials were conducted during the spring and summer of 1955, using 12 wether lambs a total of 4 collection periods. Comparisons of soybean meal and linseed meal as the high-protein ingredients in the concentrate portion of the rations were studied. The effects of added lard as an energy substitute, and urea as a protein replacement in rations were also investigated. Lard and urea were tested alone and in combination, with the effects of linseed meal, soybean meal, and lard upon the utilization of urea nitrogen being a major objective in the study of this problem.

A total of eight concentrate rations, containing approximately 19 percent protein were fed with equal amounts of late-cut prairie hay to provide rations of about 11.5 percent protein equivalent, on a dry basis. Four rations were offered every other period to three lambs each, so that six lambs received each of the treatments during the course of the trials. All lambs were fed individually twice daily at the rate of 500 grams per 100 pounds of body weight. A five percent increase in feed was provided each successive period to compensate for growth of the animals.

Coefficients of apparent digestibility of each nutrient, and nitrogen metabolism data were the measures of performance of the animals. Poor feed consumption on the part of three of the lambs during the latter periods of collection made it necessary to exclude their data from the results obtained.

From all results, there appeared to be no difference in the digestibility of nutrients in rations containing soybean meal or linseed meal for growing and fattening lambs. Digestion coefficients for the nutrients did show a slight advantage for linseed meal, but this was small and nonsignificant.

Urea, added at the rate of 0.9 percent of the total ration, did not seem to affect the digestibility of crude protein, crude fiber, nitrogen-free extract, and organic matter. There was a difference, however, in the digestibility of ether extract when urea was incorporated in the rations. This difference appeared as a significant protein x urea interaction. Urea increased the digestibility of ether extract in the soybean meal rations, but decreased the digestibility of ether extract in the linseed rations. This effect was significant at the 5 percent level.

Urea proved to be a satisfactory source of protein under the conditions of these trials. Important considerations in its use in rations for lambs are its cost as a source of protein, the protein level of the ration, and the level of urea used to supplement the conventional protein in rations.

Five percent added lard in rations for lambs significantly increased protein and ether extract digestibility, but depressed the digestibility of crude fiber and nitrogen-free extract. However, there was no effect of lard on the digestibility of total organic matter. Apparently, the increase in digestibility of crude protein and ether extract was great enough to offset the depression in crude fiber and nitrogen-free extract digestibility. This resulted in rations about equal in digestible organic matter, but the higher level of fat in the rations containing lard gave them a higher energy value.

There appeared to be no difference in digestibility of nitrogen from urea when the rations contained linseed meal or soybean meal. This indicates that the two high-protein ingredients have about the same value as protein supplements when used with urea for fattening lambs. Lard improved the apparent digestibility of protein of rations containing urea, but to about the same degree as for rations with no urea. Apparently, lard had no specific effect on digestibility of urea nitrogen.

The nitrogen balance data did not show any significant differences between the various treatments. The data was somewhat variable and rations containing urea without lard gave the lowest values for percent of consumed nitrogen retained. Nitrogen in rations containing both urea and lard appeared to be retained better than the nitrogen in rations with urea but no lard. This improvement appeared to result from an increase in digestibility of protein when lard was added to the rations.

From these results, it appears that lard is a satisfactory feed for fattening lambs when used at levels up to 5 percent of the total ration. Lard used in this experiment was highly digestible and no doubt this would be an important factor in the comparative value of other fats with lard.

The practical value of adding lard to rations for fattening lambs will depend largely on the comparative price with grains as a source of energy, and upon the type of rations being fed. The decrease in digestibility of crude fiber may limit the value of lard in high roughage rations. The increase in digestibility of protein and improvement of handling and mixing qualities of the feed will give the lard some extra value. Adding lard to the feed appears to have no special effect on the utilization of urea nitrogen.

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APPENDIX TABLES I

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Soybean Basal Ration.

Lamb No.	Dry Matter Fed Hay Gms.	Dry Matter Fed Conc. Gms.	Dry Matter Refused Gms.	Nutrients Consumed: Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
Per. 2										
2	3444	3481	484	6441	719	186	1207	3919	5926	4155
3	2952	2979	—	5930	656	167	1120	3499	5442	3861
11	3120	3155	—	6274	694	177	1184	3703	5758	3930
Per. 4										
5	3329	3432	—	6761	852	189	1297	3874	6212	3675
8	3675	3787	621	6841	889	185	1253	3966	6293	3897
12	2906	2989	—	5895	742	165	1133	3377	5416	3623
				Coefficients of Apparent Digestibility						
				%	%	%	%	%	%	%
Per. 2										
2				64.5	54.8	13.7	63.2	75.0	67.8	64.5
3				66.2	63.2	40.9	63.7	73.7	69.4	65.1
11				64.2	58.3	25.2	57.1	74.2	67.3	62.6
Per. 4										
5				53.8	56.3	21.6	52.8	62.4	58.4	54.4
8				58.4	63.9	28.5	45.3	66.6	60.9	57.0
12				62.6	62.7	33.1	58.1	70.4	65.6	61.4

APPENDIX TABLES II

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Soybean-urea Ration.

Lamb No.	Dry Matter Fed Hay Gms.	Dry Matter Fed Conc. Gms.	Dry Matter Refused Gms.	Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
				Nutrients Consumed						
Per. 1										
6	2740	2721	261	5200	579	176	876	3214	4845	3074
8	3146	3132	---	6277	685	214	1095	3845	5839	3858
11	2905	2890	---	5795	632	198	1011	3549	5390	3740
Per. 3										
2	3542	3595	2325	4812	498	203	939	2778	4418	2942
7	3186	3237	---	6423	720	261	1178	3733	5892	4120
10	3542	3595	129	7008	783	286	1290	4074	6432	4104
				Coefficients of Apparent Digestibility						
				%	%	%	%	%	%	%
Per. 1										
6				58.9	57.5	27.6	37.7	71.6	62.2	59.1
8				61.6	61.4	29.8	49.6	71.5	64.7	61.5
11				63.6	60.9	50.0	53.7	73.0	67.1	64.5
Per. 3										
2				60.2	46.6	57.5	59.1	68.1	63.3	61.1
7				63.7	55.2	56.2	57.4	72.8	66.8	64.1
10				59.0	60.9	52.1	52.2	66.1	62.0	58.6

APPENDIX TABLES III

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Soybean-lard Ration.

Lamb No.	Dry Matter Fed: Hay Gms.	Dry Matter Fed: Conc. Gms.	Dry Matter Refused Gms.	Nutrients Consumed: Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
Per. 1										
4	3399	3437	581	6256	756	552	1020	3470	5788	4417
5	2867	2893	—	5760	667	478	1008	3164	5315	3777
12	2486	2502	—	4988	577	414	872	2740	4602	3374
Per. 3										
1	3047	3050	234	5862	698	459	1030	3140	5348	3903
3	3034	3037	2642	3429	429	291	599	1789	3107	2537
9	3034	3037	737	5335	668	442	893	2861	4868	3458

Lamb No.				Coefficients of Apparent Digestibility: Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N. F. E. %	Organic Matter %	T. D. N. %
Per. 1										
4				65.3	69.9	70.0	49.6	72.5	68.0	70.6
5				60.6	62.2	65.3	49.2	68.4	63.7	65.6
12				62.1	69.0	72.0	51.9	67.7	65.5	67.6
Per. 3										
1				62.3	67.3	74.8	48.3	68.6	65.0	66.6
3				70.3	67.1	79.5	54.2	78.6	72.4	74.0
9				59.6	62.4	76.6	47.0	65.0	62.4	64.8

APPENDIX TABLES IV

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Soybean-urea-lard Ration.

Lamb No.	Dry Matter Fed Hay Gms.	Dry Matter Fed Conc. Gms.	Dry Matter Refused Gms.	Nutrients Consumed: Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
Per. 2										
5	3068	3050	125	5993	689	486	1099	3227	5450	3997
8	3366	3343	43	6666	760	533	1237	3589	6117	4307
9	2952	2936	287	5601	646	450	1025	3025	5146	3692
Per. 4										
7	3367	3397	—	6764	812	593	1285	3520	6210	4132
10	3739	3766	587	6917	847	620	1282	3606	6354	4468
11	3406	3422	914	5913	767	555	1011	3110	5442	4125

Lamb No.	Coefficients of Apparent Digestibility: Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N. F. E. %	Organic Matter %	T. D. N. %
Per. 2							
5	63.4	63.8	56.5	58.6	71.2	66.4	66.7
8	60.7	62.3	64.7	51.7	67.4	63.4	64.6
9	61.4	63.2	64.7	49.7	70.1	64.7	65.9
Per. 4							
7	55.7	65.6	75.7	44.6	57.3	57.5	61.1
10	58.6	64.6	75.6	44.5	63.7	61.1	64.6
11	62.8	70.5	79.9	49.5	67.1	65.6	69.8

APPENDIX TABLES V

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Linseed Basal Ration.

Lamb No.	Dry Matter Fed Hay Gms.	Dry Matter Fed Conc. Gms.	Dry Matter Refused Gms.	Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
				Nutrients Consumed						
Per. 1										
3	2732	2733	—	5486	658	171	994	3318	5079	3491
7	2892	2879	—	5771	693	180	1041	3492	5344	3782
10	3209	3197	—	6406	769	199	1159	3876	5931	4066
Per. 3										
6	3021	3059	2330	3750	552	78	490	2337	3456	2328
8	3453	3507	89	6871	829	185	1275	3990	6279	4049
11	3199	3246	—	6445	779	174	1193	3744	5890	3841
				Coefficients of Apparent Digestibility						
				%	%	%	%	%	%	%
Per. 1										
3				63.0	65.5	34.0	56.9	70.7	66.1	63.6
7				64.8	68.9	32.8	57.6	73.2	68.2	65.5
10				63.4	62.7	10.6	54.2	74.6	66.9	63.5
Per. 3										
6				63.9	65.0	22.1	37.0	74.9	66.7	62.1
8				59.8	59.2	40.2	52.7	68.2	63.0	58.9
11				59.9	61.9	54.0	50.3	68.1	63.2	59.6

APPENDIX TABLES VI

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Linseed-urea Ration.

Lamb No.	Dry Matter Fed Hay Gms.	Dry Matter Fed Conc. Gms.	Dry Matter Refused Gms.	Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
				Nutrients Consumed						
Per. 2										
4	3638	3668	—	7303	790	209	1364	4370	6733	4621
6	2928	2947	918	4955	585	149	816	3043	4392	3033
7	3094	3124	—	6218	673	178	1160	3721	5033	3882
Per. 4										
1	3226	3293	105	6415	784	162	1257	3676	5968	3620
3	3214	3281	2714	3780	493	62	773	2138	3467	2236
9	3214	3281	497	5997	736	149	1175	3437	5497	3502
				Coefficients of Apparent Digestibility						
				%	%	%	%	%	%	%
Per. 2										
4				64.6	63.4	20.5	59.1	73.6	67.8	63.3
6				62.0	56.9	16.7	54.4	72.3	65.4	61.2
7				63.4	61.3	22.3	56.3	73.3	66.8	62.4
Per. 4										
1				58.3	62.4	14.6	53.6	65.4	61.6	56.4
3				63.2	69.7	-25.0	66.9	66.9	65.6	59.7
9				59.6	62.0	30.8	54.0	67.1	62.7	58.4

APPENDIX TABLES VII

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Linseed-lard Ration.

Lamb No.	Dry Matter Fed: Hay Gms.	Dry Matter Fed: Conc. Gms.	Dry Matter Refused Gms.	Nutrients Consumed: Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
Per. 2										
1	2965	2950	—	5914	723	497	1157	3013	5389	3832
10	3444	3433	—	6877	841	578	1344	3504	6266	4603
12	2667	2657	—	5324	651	447	1041	2713	4851	3571
Per. 4										
2	3739	3774	2456	5057	620	401	1014	2615	4651	3312
4	3969	4003	972	7000	898	590	1290	3642	6420	4781
6	3188	3215	2470	3933	540	368	620	2106	3633	2465
				Coefficients of Apparent Digestibility						
				%	%	%	%	%	%	%
Per. 2										
1				60.0	65.7	71.8	50.8	65.3	62.8	64.8
10				61.9	67.5	72.4	47.8	70.0	65.1	66.9
12				61.9	65.5	73.2	50.8	69.3	65.2	67.1
Per. 4										
2				60.3	65.0	75.9	56.5	63.1	63.0	65.5
4				62.7	69.6	81.5	47.3	67.7	65.1	68.3
6				54.7	64.2	77.7	27.2	62.1	58.0	62.7

APPENDIX TABLES VIII

Feed Consumption and Coefficients of Apparent Digestibility for Lambs Fed Late-cut Prairie Hay and Linseed-urea-lard Ration.

Lamb No.	Dry Matter Fed: Hay Gms.	Dry Matter Fed: Conc. Gms.	Dry Matter Refused Gms.	Nutrients Consumed: Dry Matter Gms.	Crude Protein Gms.	Ether Extract Gms.	Crude Fiber Gms.	N. F. E. Gms.	Organic Matter Gms.	T. D. N. Gms.
Per. 1										
1	2765	2723	43	5448	649	501	968	2913	5031	3621
2	3209	3169	1143	5234	673	542	828	2792	4864	3636
9	2752	2762	95	5419	651	503	951	2902	5007	3832
Per. 3										
4	3757	3786	926	6618	842	592	1123	3514	6071	4392
5	3148	3168	—	6316	762	533	1140	3347	5783	4070
12	2742	2764	60	5446	658	461	980	2889	4988	3436

Lamb No.	Coefficients of Apparent Digestibility: Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	N. F. E. %	Organic Matter %	T. D. N. %
Per. 1							
1	60.8	69.4	66.8	47.9	67.1	63.7	66.5
2	61.6	68.2	75.6	44.0	67.7	64.8	69.5
9	63.9	69.9	77.9	50.6	69.4	66.8	70.7
Per. 3							
4	60.0	64.1	74.9	38.5	68.9	63.2	66.4
5	58.7	60.7	75.5	46.8	64.8	61.7	64.4
12	57.4	62.0	74.2	48.8	61.6	60.3	63.1