I. A STUDY OF THE NUTRITIVE VALUE OF RUMEN CONTENTS

II. FACTORS AFFECTING THE DIGESTIBILITY OF LOW QUALITY ROUGHAGES BY LAMBS

By

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I. A STUDY OF THE NUTRITIVE VALUE OF RUMEN CONTENTS

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PART I

INTRODUCTION

Approximately 13 million cattle and 15 million sheep are slaughtered annually in the United States. The average cattle rumen will contain about 100 pounds of material which will consist of 10 - 15 percent dry matter. On the basis of these figures there is available in the United States each year more than 65,000 tons of dry rumen material from the slaughter of cattle alone. In the past rumen contents have been processed for building-insulation material and have been used to a limited extent in fertilizers. However, today most packing houses discard this material as a waste product. This often presents a serious disposal problem. Since the synthesis of almost all of the B vitamins has been demonstrated to take place in the rumen, it is possible that rumen contents might be processed and have considerable value as a vitamin supplement. Rumen contents also contain between 7 and 15 percent crude protein, which in all probability is of excellent quality. On the other hand rumen contents contain from 20 - 40 percent crude fiber, a factor which would tend to markedly reduce their value as a supplement to livestock and poultry feeds.

This study has been made in an attempt to determine some of the factors concerning the nutritive value of rumen contents. Two separate experiments were conducted. The first experiment was conducted in order to determine the proximate and B vitamin composition of rumen contents collected from cattle and sheep fed various rations. The second experiment concerned the vitamin B complex value of rumen contents collected from sheep fed equal quantities of rations widely different in composition.

REVIEW OF LITERATURE

Thieler, Green, and Viljoen (1915) were probably the first to suggest that what was then known as vitamin B might be synthesized in the digestive tract of cattle. These workers observed that ruminants could be maintained for long periods of time on a diet very low in vitamin B. They stated that, "We think it as least possible that the vitamin requirements of cattle are so low that they may even be covered indirectly by synthesis carried out by the extensive bacterial flora of the intestine." This observation was followed by the work of Shunert and Shieblich (1923) who demonstrated that Bacillus vulgatus, an organism found in the digestive tract of ruminants, synthesized vitamin B.

In a study concerning the vitamin B requirement of calves, Bechdel et al., (1927) produced conclusive evidence that the vitamin B in milk is not dependent on the presence of this vitamin in the ration of the cow. Three cows, which were fed for over two years throughout their growth period on a ration that was practically devoid of the vitamin B complex as demonstrated by rat assay methods, were used in this study. The evidence obtained appeared to indicate that cattle possess the ability to synthesize vitamin B. Bechdel et al., (1928) later demonstrated that the synthesis of vitamin B took place in the rumen. In this experiment a Holstein heifer which had grown to maturity on a B vitamin-deficient ration was equipped with a rumen fistula in order that rumen contents could be removed for analysis. Twelve hours after feeding, portions of the ingesta were removed from the rumen, placed in a can, and incubated at $37^{\circ}C$ for five days. The material was then extracted with alcohol and a concentrate made. This concentrate was assayed with rats and was found to possess vitamin B activity.

Following these more or less pioneer experiments more detailed research was undertaken in order to determine whether or not all of the vitamins were synthesized in the rumen and to a lesser degree the quantities of these materials which were produced by rumen synthesis.

McElroy and Goss have conducted a series of experiments in which they have found that vitamin K (1940a), riboflavin (1940a), pyridoxine (1940b), thiamin (1941a) and pantothenic acid (1941b) were synthesized in the rumen. These workers fed sheep a ration practically devoid of B vitamins and at the end of a 30-day period the sheep were slaughtered, and the contents of the rumen and reticulum were recovered. They also collected rumen contents from a fistulated cow fed a similar ration. Chicks were used as assay animals with the exception that rats were used in the pyridoxine experiment. The chicks were made deficient by feeding them a basal ration low in the vitamin to be assayed. The basal ration was then supplemented with the dried rumen contents and the growth rate of this lot of chicks was compared to other lots receiving the basal diet supplemented with various levels of the synthetic vitamin. One lot of chicks was continued on the basal ration and another group of chicks was fed the basal ration plus the ration fed the animals from which the rumen contents were obtained. By using this type of assay it was possible to determine approximately how much more of the vitamin was in the rumen contents than was present in the ration.

The following table was prepared from research conducted by McElroy and Goss (1940a, 1940b, 1941a, 1941b). These workers were unable to detect thiamin in the rumen contents of fistulated cows. However, the milk from one of these cows was found to contain more thiamin than was present in the ration of this animal. McElroy and Jukes (1940), using a technique similar to the one previously described, were able to demonstrate biotin synthesis in the rumen.

Vitamim Content of Dry Rumen Material

Vitamin	Vitamin content per gram of ration* (micrograms)	Vitamin content per gram of rumen contents** sheep (micrograms)	cow (micrograms)
Riboflavin	0.3	33.	25
Pyridoxine	1.0-1.5	10.	8
Thiamin	0.4	7.	none
Panthothenic acid	2.8	70.	60-80

* The experimental ration consisted of washed casein 5%, washed sardine meal 6.7%, glucose 11.0%, corn starch 10.6%, mineral mixture 3%, and dried plain sugar beet pulp 63.7%.

** Rumen contents were removed from each animal 14 hours following the last feeding.

Several other workers have substantiated and extended the work of McElroy and Goss. Wegner and associates (1945) fed a fistulated calf a synthetic ration and collected samples for analysis 6 hours following the last feeding. The results are presented in tabular form below:

Vitamin Content of Dry Rumen Material
Obtained from a Rumen-Fistulated Calf

Factor	Basal Ration* Microgms./gm	Assay Method	Rumen Contents Microgms./gm	Rumen Contents (thiamin added to ration) Microgms./gm
Thiamin	0.	chick	10-12	20+
Riboflavin	0.4	microbiological	18.6	26.5
Nicotinic acid	60.	chemical	220	172
Pantothenic acid	3.4	microbiological	55.5	82.5
Pyridoxine	0.	rat	7	11-12
Biotin	0.018	microbiological	0.087	0.250

* The ration fed the fistulated calf consisted of acid-washed casein 4%, urea 1.0%, cod liver oil 1.0%, salt mixture 3.0%, corn molasses 10.0%, corn starch 71%, and bleached wood pulp 10.0%. The calf was fed twice daily and received two pounds of ration per feeding.

Other workers had suggested that thiamin was possibly destroyed in the rumen. To investigate this possibility 200 mg. of thiamin was added to the calf ration and the rumen contents were again assayed for members of the B complex. These results are recorded in the last column of the preceding table Apparently the thiamin was not destroyed in the rumen and the addition of thiamin to the ration actually appeared to increase the synthesis of the other B vitamins. It should be noted however that only one animal was used in this experiment. The apparent synthesis of other members of the B complex when thiamin was added to the ration could have been due to other factors.

In a later paper Wegner and associates (1941) fed a natural ration consisting of timothy hay, corn silage, and a grain mixture of corn and oats. They again were able to demonstrate the synthesis of six members of the B complex as measured by an increase in the amount found in the rumen over the amount present in the ration. The addition of nitrogen, either in the form of linseed oil meal or urea, failed to increase the synthesis of B vitamins. This finding was in disagreement with that of Lardinois et al., (1944).

Hunt and co-workers (1941) collected rumen contents from fistulated steers at 4, 12, and 16 hours following the last feeding. The steers were fed various rations and rumen contents were collected for analysis. Following collection, the rumen contents were preserved with alcohol, dried in a low temperature oven and assayed for riboflavin and thiamin. Rats were used as the assay animals. The results obtained indicated that riboflavin was synthesized in the rumen when a ration of alfalfa hay, yellow corn and a protein supplement was fed. More riboflavin per gram of rumen contents was found to be present 16 hours following the last feeding than was present 4 hours following the last feeding. No synthesis of riboflavin could be detected when alfalfa hay was fed alone. The data also indicated a greater thiamin content per gram of dried rumen material removed 4 hours after feeding than was present in the feed, and a decreased content 12 or 16 hours after feeding. From the results obtained it would appear that thiamin was absorbed rather rapidly or was destroyed in the rumen.

In a similar experiment Hunt and co-workers (1943) were again able to demonstrate that riboflavin was synthesized in the rumen of the steer when a ration containing corn, alfalfa hay, and a protein supplement was fed. When corn was omitted from the alfalfa hay-protein supplement rations there was no apparent synthesis of riboflavin. As the amount of corn in the ration was increased there was a corresponding increase in riboflavin per gram of rumen contents. When ground corn was fed, the rumen contents appeared to contain more riboflavin than when a similar ration containing an equal weight of whole corn was fed. These workers also fed a partially-synthetic, low-vitamin ration and obtained results which seemed to indicate that the amount of carbohydrates in the ration and the riboflavin content of the dried rumen material were correlated. The synthesis of thiamin in the rumen could not be demonstrated in this experiment.

Lardinois et al., (1944) have reported the effect of nitrogen added to the ration as urea on the extent of the vitamin B complex synthesis in the rumen of the fistulated cow and calf. They attempted to determine whether or not there was any correlation between added nitrogen and readily fermentable carbohydrate on vitamin synthesis in the rumen. The data obtained from rumen samples collected from the fistulated cow are presented below. Similar results were obtained from the fistulated calf.

The authors stated that, "The addition of nitrogen as urea resulted in increased synthesis of nicotinic acid, biotin, riboflavin, and pantothenic acid in the rumen, but significantly only when molasses or a readily fermentable carbohydrate was supplied with the ration." Since these workers did not feed urea when a readily fermentable carbohydrate was not present in the ration, it was difficult to understand their statement. However, it appeared that urea

Vitamin Content of Dry Rumen Material Obtained
from a Rumen-Fistulated Cow Fed Various Rations

Ration	Ration No.	Thiamin*	Ribo-flavin*	Nicotinic acid*	Pantothenic acid*	Biotin**	Folic acid*	Pyri-doxine*
Timothy Hay (12 lbs.)	1	0.17	6.7	31.0	3.4	207	0.42	2.6
Timothy Hay (10 lbs.) and Corn Molasses (4 lbs.)	2	0.24	7.6	39.6	3.9	253	0.33	2.6
Same as 2 plus 200 gms. urea	3	0.36	13.6	64.7	12.0	277	0.42	4.2
Timothy Hay (10 lbs.)	4	0.18	7.7	35.2	5.8	207	0.52	2.6
Timothy Hay (10 lbs.) Corn Molasses (2 lbs.) Starch (2 lbs.)	5	0.18	5.3	30.9	5.7	212	0.31	2.5
Same as 5 plus 200 gms. urea	6	0.08	12.7	65.6	17.9	289	0.57	4.3
Same as 5 plus acid washed casein (0.2 lbs.)	7	0.12	11.5	56.6	18.2	250	0.34	2.8
Same as 7 plus 200 gms. urea	8	0.35	12.0	59.0	16.3	309	0.49	2.6

* Micorgrams per gram of dry rumen material.

** Millimicrograms per gram of dry rumen material.

enhanced riboflavin and pantothenic acid synthesis when added to a ration of prairie hay and a readily fermentable carbohydrate. There also appeared to be some synthesis of pyridoxine when this type of ration was fed. Thiamin synthesis in the rumen was not demonstrated in this experiment.

Frey and Kratzer (1945) determined the amount of thiamin, riboflavin, pantothenic acid and nicotinic acid in rumen contents from feed lot steers. Seven composite samples, from 140 steers were analyzed. Each composite sample consisted of equal amounts of the rumen contents collected from twenty steers. The steers had apparently been fed a fattening ration. However, no mention was made regarding the rations fed nor the time of collection following the last feeding of the steers. The results of the analysis are presented in the following table.

Vitamin Content of Dry Rumen Material
Obtained from Steers

Vitamin	Lowest Value Found Microgms./gm	Highest Value Found Microgms./gm	Average of 7 Composite Samples Microgms./gm
Thiamin	8.3	13.0	10.0
Riboflavin	9.7	13.0	12.0
Nicotinic acid	30.0	62.0	43.0
Pantothenic acid	39.0	66.0	49.0

A limited study of the nutritive value of rumen contents has been made by Booth and Hart (1942). These workers heated rumen contents to 194°F, pressed out the fluid and then evaporated the fluid to dryness at a relatively low temperature in order to preserve the vitamins. The concentrate which they obtained in this manner contained 17 to 20 micrograms of riboflavin per gram. No mention was made regarding the conditions under which the rumen contents were obtained.

Rumen contents from cobalt deficient sheep and from cobalt supplemented sheep were assayed for vitamin B_{12} activity by Hale *et al.*, (1949). Chickens were used as assay animals. Five trials showed that some growth factor(s) was missing from the rumen contents of the deficient sheep. The rumen contents of the cobalt supplemented sheep consistently gave from 30 to 40 grams more chick growth during the assay period of 4 weeks than did the rumen contents from the cobalt deficient sheep. This slower growth rate could be completely overcome by adding vitamin B_{12} to the ration of rumen contents from the cobalt deficient sheep.

Burroughs et al., (1946) using two rumen-fistulated steers, conducted an extensive study of the amounts of feeds and nutrients present in the rumen at 4-hour intervals for 24-hour periods. The ingesta examinations included total weights of water and dry matter in the rumen and reticulum as well as complete proximate analyses of this material. The three rations fed were similar in all respects except for the form of corn fed, which was shelled corn, ground corn and ground ear corn. These rations were compared at a low, medium, and high plane of nutrition.

The following table from Burroughs et al., (1946) demonstrates that the value of rumen contents, in so far as the major nutrients are concerned, is dependent upon the time of removal of ingesta following the last meal.

Nutrients Present in the Rumen at Various Intervals Following Ingestion of Feed. Weights are in Pounds 1, 2

Time	Water	Dry Matter	Nitrogen-Free Extract	Crude Fiber	Protein NX6.25	Ether Extract	Ash
8 A. M.	40.7	4.9	2.2	1.1	0.9	0.2	0.5
8:30 Feed & Water	59.8	10.1	5.4	1.8	1.8	0.4	0.7
12 Noon	56.8	7.5	3.6	1.5	1.5	1.4	0.7
4 P. M.	47.1	6.3	3.1	1.2	1.2	0.3	0.6
4:30 Feed & Water	62.9	11.5	6.3	1.9	2.1	0.5	0.8
8 P. M.	58.3	9.2	4.8	1.6	1.7	0.4	0.7
12 Night	50.3	7.1	3.5	1.4	1.4	0.3	0.6
4 A. M.	44.4	6.1	2.8	1.3	1.2	0.2	0.6
8 A. M.	38.3	5.2	2.5	1.1	1.0	0.2	0.5

1. The ration fed consisted of ground shelled corn 6.5 pounds, alfalfa hay 3.5 pounds, and protein supplement 1.3 pounds. The protein supplement contained soybean meal 35%, cottonseed meal 35%, tankage 25%, limestone 2%, bone meal 1% and salt 1%.
2. Each figure represents an average of 12 determinations.

The data presented in the following table abstracted from Burroughs et al., (1946) demonstrates that the value of rumen contents in so far as the major nutrients are concerned is dependent upon the plane of nutrition.

Nutrients Found in the Rumen at Different Levels of Feeding
Weights are in pounds and each figure is an average of 12 determinations, using two steers.

Water	Ration Level	Dry Matter*	Nitrogen Free Extract	Crude Fiber	Crude Protein	Ether Extract	Ash
28.3	Low	2.8	0.9	1.0	0.5	0.1	0.3
41.5	Medium	4.4	1.8	1.1	0.9	0.1	0.5
56.4	High	7.3	3.2	1.7	1.4	0.2	0.8

* All samples collected approximately 15 hours following last feeding

These workers found that total dry matter in the rumen was highest immediately following feeding and decreased until the following feeding period. At the low level of feeding, this decrease was found to be fairly constant from period to period. As the plane of nutrition increased, the dry matter tended to disappear from the rumen more rapidly shortly after feeding than it did at each succeeding period thereafter.

The total protein in the rumen varied with the amount fed or the plane of nutrition. The protein appeared to leave the rumen at about the same rate as did the total dry matter. Thus, the ratio of protein to dry matter was approximately the same at one period of the day as compared with most any other period.

The total carbohydrate in the rumen at different periods of the day paralleled the amounts of dry matter and protein found in the paunch throughout a 24-hour period. However, this was not true in the case of the two carbohydrate fractions, nitrogen-free extract and crude fiber. At all levels of feeding the nitrogen-free extract tended to leave the rumen much more rapidly after feeding and to reach much lower levels just prior to feeding than did the crude fiber. The rate at which crude fiber left the rumen was fairly constant.

A physical examination was made of the rumen samples collected. It was observed that ground shelled corn left the rumen at a faster rate than did shelled corn. Corn cobs remained in the rumen for a longer period of time than hay. The estimated amount of hay in the rumen was consistently high when a ground ear corn ration was fed. Considering the added amount of roughage as cobs in the ground ear corn, the total roughage in the rumen was considerably higher with this ration than was the case with the other two rations. It was noticed that the cobs had the ability to soak up large quantities of water. Evidence that cobs imbibe more liquid than do hays was observed by the relative position which these two feeds occupy in the rumen. When ground cobs were added to the hay-grain ration they tended to stratify in the water layer of the ingesta beneath that of the hay. This phenomenon may be an important factor in the digestion and utilization of corn cobs. Also the fact that the cobs remained in the rumen for a longer period of time would be a factor favoring their microbiological digestion.

It should be noted that this data may be subject to some experimental error. The use of fistulated animals combined with the procedure of removing the total rumen contents necessitated considerable aeration of this material. This procedure is probably detrimental to the rumen microorganisms which are mostly anaerobes.

A few experiments have been reported in which rumen contents have been included in rations for poultry and swine. Two Italian workers, Uselli and Fiorini (1939), divided rumen contents into what they referred to as "bacterial," "nutritive," and "infusorial" fractions. These workers did not describe their methods of separating the rumen material into these different fractions, but they stated that this was done by a series of successive dilutions, centrifugations and decantations. The fractions were added to a basal ration of corn, supplemented with minerals and vitamins. Sixteen White Leghorn males were equally divided into four lots. The various fractions were fed at the rate of two grams per bird per day. One group was used as a control. The chickens receiving the infusorial fraction appeared to gain a little faster then the other groups. The authors attributed this apparent increase in weight to protein quality. No mention was made as to the conditions under which the rumen contents were collected.

In what appeared to be a well-conducted experiment, Hammond (1944) tested the value of various combinations of conventional feed stuffs, dried cow manure, and dried rumen contents, as a substitute for alfalfa leaf meal in an all-plant ration for chicks. No mention was made regarding the time of collection following the last feeding nor to the ration the cattle were fed from which the rumen contents were obtained. The rumen contents used in this study analyzed 14.4 percent protein, 8.4 percent ash, 1.5 percent fat, 38.5 percent crude fiber, and 33.5 percent nitrogen-free extract. The rumen contents were also assayed for riboflavin and were found to contain approximately 14 micrograms per gram of dried rumen material.

Chicks fed 8 percent dried rumen contents or dried cow manure in the place of alfalfa meal made more rapid gains than those fed alfalfa leaf meal or other conventional plant feed mixtures. Efficiency of feed utilization was higher for the chicks fed rumen contents or dried cow manure. Later studies have indicated that vitamin B_{12} was at least one factor present in the rumen contents and cow manure which contributed to the increased growth and feed efficiency of the chicks.

Ferrin (1946) conducted a study in which dried paunch contents from cattle were substituted for 8 percent of the ground yellow corn in rations for growing pigs when tankage was the principal source of protein. The pigs gained as well on the experimental ration as they did the control ration with a somewhat more efficient utilization of feed consumed.

Dried whey, alfalfa meal, irradiated yeast, niacin, riboflavin and iodized salt were included in all rations. The pigs used in this experiment had an average initial weight of 49 pounds. Ten pigs were placed in each lot and were restricted to pens having concrete floors. During the first 49 days of the feeding period, the average daily gain per pig was 1.47 pounds in the lot receiving tankage and 1.46 pounds in the lot receiving tankage plus rumen contents. The feeds consumed per hundred pounds of gain were 370 and 352 pounds, respectively.

No mention was made as to the ration the cattle were fed, nor to the time of collecting the rumen contents following the last feeding of the cattle.

EXPERIMENT I

The purpose of this experiment was to gain information regarding the nutritive value of rumen contents collected from grass-fed and grain-fed cattle.

Procedure

Rumen contents were collected from cattle which had been grazing native range pasture during the early summer season, and from cattle which had been full-fed a ration of corn and other cereal grains, cotton seed cake, sorghum silage and alfalfa hay. The rumen contents were collected immediately following the slaughter of the cattle. Some of the samples were obtained at the college meats laboratory and the remainder from commercial packing plants in Oklahoma City. The material from both the rumen and reticulum was collected in a large container, mixed thoroughly, and sampled for analysis. These samples were either dried immediately in a low temperature oven or quick frozen until a time when they could be dried. Other similar samples were separated into two fractions. The complete rumen contents were placed in a lard press and the liquid portion of the rumen material was pressed out. This liquid portion is referred to in the following tables as rumen liquor and the solid material as rumen residue. The rumen liquor was quick frozen until it could be analyzed, while the rumen residue was immediately dried in a low temperature oven (40-50°C). Proximate analyses were made in the usual manner by the Agricultural Chemistry Research Department. The riboflavin and nicotinic acid content of rumen materials was determined microbiologically by the author.

RESULTS AND DISCUSSION

The results of this experiment are presented in Tables 1 through 6. The chemical analyses of rumen contents obtained from a grass-fed cow and four grain-fed steers are presented in Tables 1 and 2, respectively. A comparison of the values presented in these two tables gives some idea of the effect of ration on the nutritive value of rumen contents. The rumen contents collected from steers on a fattening ration were higher in protein and fat, and considerably lower in fiber than the rumen contents collected from the grass-fed cow. Evidence is also presented (Tables 1, 2, 3, and 4) that the time of collecting the rumen contents following the last feeding of the animals is an important factor in determining the nutritive value of this material. For example, the composite sample of rumen contents obtained from 4 grain-fed steers, (Table 2) slaughtered 16 hours following the last feeding, contained 15.5 percent crude protein, 4.3 percent ether extract, 32.3 percent crude fiber, and 40.0 percent nitrogen-free extract. The composite sample of rumen contents, obtained from 40 grain-fed steers slaughtered 36 hours following the last feeding, contained 7.3 percent crude protein, 3.0 percent ether extract, 23.8 percent crude fiber and 47.1 percent nitrogen-free extract. Thus, the rumen contents collected 16 hours following the last feeding were higher in crude protein and ether extract than rumen contents collected 36 hours following the last feeding. However, the rumen contents collected 36 hours following the last feeding were lower in crude fiber. Needless to say, the quantity of dried rumen material collected from full-fed cattle slaughtered

16 hours following the last feeding was considerably greater than that collected from steers slaughtered 26 hours following the last feeding. These findings are in agreement with the work of Burroughs et al., (1946) who conducted a controlled experiment using fistulated steers as the experimental animals.

Composite samples collected from grass-fed cattle at a commercial packing plant in Oklahoma City are presented in Table 3. These samples are believed to be fairly typical of the rumen contents collected at packing plants in the southwestern part of the United States during the early summer grazing season. This material contained approximately 80-90 percent moisture, and this alone presents a problem in processing the material for feeding purposes. The dried rumen material contained a fair percentage of protein but it was quite high in fiber, a factor which would limit its use in poultry and swine rations.

An attempt was made to concentrate the soluble nutrients by separating the rumen contents into rumen liquor and rumen residue as described under procedure. It was thought that the rumen liquor might contain considerable amounts of protein and vitamins. Chemical analyses of rumen liquor (Tables 1, 2, and 5) showed this material to contain from 1.5 to 3.2 percent dry matter, 12 to 25 percent of which was crude protein. This dried rumen liquor contained 35 to 50 percent ash of a very alkaline nature. The nicotinic acid and riboflavin content of rumen liquor and rumen residue are presented in Table 6. Rumen liquor, reported on a dry matter basis, was found to contain considerable nicotinic acid and roboflavin, but not nearly enough for it to have merit as a commercial source of these vitamins.

The results of this study indicate that rumen contents from grass-fed cattle collected from a commercial packing plant, under the usual prevailing conditions has very little value as a feeding supplement due to its high water and fiber content. However it appears possible that means of processing this material might be developed which would increase its nutritive value. Contrary to suggestions made by other workers, rumen contents collected under commercial conditions were not found to be a superior source of the vitamin B complex as measured by nicotinic acid and riboflavin content. It should be kept in mind that cattle slaughtered at commercial packing houses have been fasted for several hours during which time most of the residual feed materials normally present in the rumen have been absorbed and utilized by the animals.

Table 1

Chemical Analysis of rumen Contents Collected from One Grass-fed Cow Slaughtered at the College Meat Laboratory*

Sample	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen Free-extract %	Ash %
Rumen Contents**	8.5	1.3	46.1	34.3	9.8
Rumen Residue**	8.8	1.6	46.3	38.0	5.3
	Water %	Total Solids %	Crude Protein %		Ash %
Rumen Liquor	98.3	1.71	.22		.86

* These rumen contents were collected 16 hours following the last feeding of the cow.

** Rumen contents and rumen residue reported on a dry matter basis.

Table 2

Chemical Analysis of a Composite Sample of Rumen Contents Collected from Four Grain-fed Steers* Slaughtered at the College Meat Laboratory**

Sample	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen Free-extract %	Ash %
Rumen Contents***	15.5	4.3	32.3	39.1	8.8
Rumen Residue***	15.0	4.6	33.5	40.2	6.7
	Water %	Total Solids %	Crude Protein %		Ash %
Rumen Liquor	96.8	3.2	.81		1.1

* These steers had been full fed a ration consisting of 5 parts rolled oats, 1½ parts rolled barley, 1 part ground corn, 1½ parts wheat bran, 1 part silage and a limited amount of alfalfa hay.

** These rumen contents were collected 16 hours following the last feeding of the steers.

*** Rumen contents and rumen residue are reported on a dry matter basis.

Table 3

Chemical Analysis of Composite Samples of Rumen Contents Collected from 30 Grass-fed Steers and 29 Grass-fed Cows Slaughtered at a Commercial Packing Plant in Oklahoma City* (dry matter basis)

Sample	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen free-extract %	Ash %	Calcium %	Phosphorus %
Rumen contents composited from 30 steers	11.7	3.2	37.8	32.5	14.8	0.8	0.8
Rumen contents composited from 29 cows	10.5	2.2	33.3	38.6	15.4	0.9	0.8

* These cattle were fed some prairie hay about twelve hours prior to slaughtering.

Table 4

Chemical Analysis of a Composite Sample of Rumen Contents Collected from 40 Full-fed Steers Slaughtered at a Commercial Packing Plant in Oklahoma City[1, 2] (dry matter basis)

Sample	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen free-extract %	Calcium %	Phosphorus %
Rumen contents composited from 40 steers	7.3	2.9	23.8	47.1	0.24	0.36

[1] These steers were slaughtered about 40 hours after their last feeding of the full-fed ration. The steers were allowed access to prairie hay at the stock yards.

[2] These steers had been full-fed a ration of corn, cottonseed meal, sorghum silage and alfalfa hay.

Table 5

Chemical Analyses of Individual Samples of Rumen Material Collected from 9 Grass-fed Steers Slaughtered at a Commercial Packing Plant in Oklahoma City*

Analysis of Rumen Contents (dry matter basis)

Steer No.	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen Extract %	Ash %
1	9.4	3.2	31.8	43.0	12.7
2	9.5	2.6	31.1	44.7	12.1
3	10.2	3.2	29.2	44.1	13.3
4	9.3	2.5	31.9	45.2	11.1
5	8.0	1.8	42.9	38.9	8.5
6	9.5	1.1	32.3	45.6	11.5
7	9.0	1.4	32.5	45.8	11.4
8	8.9	1.7	33.5	44.8	11.0
9	9.5	3.1	29.4	44.2	13.9

Analysis of Rumen Liquor

Steer No.	Total Solids %	Crude Protein %	Ash %
1	-	-	-
2	1.9	0.34	0.8
3	1.8	0.41	0.8
4	1.5	0.26	0.7
5	2.3	0.70	0.9
6	1.6	0.32	0.8
7	1.6	0.26	0.9
8	1.5	0.26	0.8
9	1.7	0.35	0.8

* College steers fattened on grass at Lake Carl Blackwell range.

The rumen contents were collected approximately 36 hours after the cattle were removed from pasture. A small amount of prairie hay was fed about 12 hours prior to slaughter.

Table 6

Nicotinic Acid and Riboflavin Content of Rumen Material
Collected from 9 Grass-fed Steers*
(dry matter basis)

Steer No.	Nicotinic Acid Rumen Liquor Microgms/gm	Nicotinic Acid Rumen Residue Microgms/gm	Riboflavin Rumen Liquor Microgms/gm	Riboflavin Rumen Residue Microgms/gm
1	-	17.6	-	3.5
2	47.1	14.4	4.9	1.5
3	53.0	16.0	8.9	1.6
4	54.4	15.3	4.3	1.7
5	63.0	16.0	16.7	1.5
6	34.4	27.3	7.5	1.2
7	27.0	19.8	3.0	1.8
8	33.8	11.8	9.7	1.3
9	45.3	10.9	6.1	1.0

* Same as in Table 4.

EXPERIMENT II

This experiment was conducted in order to gain information regarding the effect of various rations on the synthesis of nicotinic acid, riboflavin and pantothenic acid in the rumen of sheep.

Procedure

Sixteen grade western wether yearling lambs ranging in weight from 70 to 90 pounds were used in this experiment, two lambs being placed on each ration. The rations fed are presented in Table 7. All lambs were fed their respective rations for a total of thirty days. They were fed in individual stanchions and when not eating were allowed the freedom of a large box stall. Fresh water was provided at all times. Salt was provided ad libitum to the lambs fed Rations 1 through 6. The lambs fed Rations 7 and 8 were allowed only the minerals included in their respective rations.

Rations 1 through 5 were fed at the rate of 800 grams per day compounded on an air dry basis. Samples of silage and hays were dried in the oven for dry matter determinations, in order that equal amounts of these materials could be fed.

Rations 1 through 5 were calculated to contain 12 percent crude protein and to be as nearly equal in total digestible nutrient content as was practical. It was necessary to provide small quantities of prairie hay for the lambs on the all-concentrate ration (Ration 5) in order to keep them on feed. However, no hay was offered these lambs for the last three days prior to slaughter. The lambs on the all prairie hay ration (Ration 6) refused to consume more than

600 grams of this relatively unpalatable ration.

Schnambye and Phillipson (1949) demonstrated that the concentration of volatile fatty acids in the rumen liquor of sheep was highest from five to seven hours following the last feeding. These acids, which are chiefly acetic, propionic and butyric, are formed as a result of the fermentation processes in the rumen. It seems reasonable to believe that vitamin synthesis in the rumen might proceed at a similar rate. Therefore, the lambs were slaughtered six hours following the last feeding.

Immediately following slaughter the total rumen and reticulum contents were removed, weighed, and large duplicate samples were taken for analysis. Within one hour after collection the ruman samples were acidified in order to minimize vitamin destruction and were autoclaved for five minutes to prevent further fermentation. The samples were then dried in a forced draft oven at approximately 80°C and were then weighed for dry matter determinations. All rumen samples and feed materials were assayed microbiologically for nicotinic acid, riboflavin, and pantothenic acid by the Agricultural Chemistry Research Department. The vitamin content of the feeds in this experiment is presented in Table 7.

RESULTS AND DISCUSSION

The results of this experiment are presented in Tables 9, 10, and 11. In this study vitamin synthesis in the rumen was measured by subtracting the vitamin content per gram of the ration from the vitamin content per gram of the dry rumen ingesta.

Information regarding the effect of the type of roughage fed on the subsequent B vitamin complex synthesis in the rumen, may be obtained by comparing the results when Rations 1, 2, and 4 were fed. These rations contained corn and soybean meal and differed only in the quantities of these two concentrates and in the type of roughage. It appears that the type of roughage fed had a direct effect on the amount of B vitamin synthesis which occurred in the rumen. For example, 115.4 and 127.5 micrograms of nicotinic acid per gram of dried rumen contents were synthesized when alfalfa hay (Ration 1) and sorghum silage (Ration 4) were fed, respectively. When prairie hay, which is a lower quality roughage, was fed (Ration 2) only 84.1 micrograms of nicotinic acid were synthesized per gram of dried rumen contents. The trend was somewhat different for riboflavin. The rumen contents obtained from lambs fed the alfalfa hay ration (Ration 1), the prairie hay ration (Ration 2), and the silage ration (Ration 4), contained 6.4, 7.0 and 10.0 micrograms of synthesized riboflavin per gram of dried material, respectively. Prairie hay appeared to favor the synthesis of pantothenic acid while silage appeared to have an inhibiting effect. The amount of pantothenic acid synthesis which occurred in the rumen was 8.0, 5.3 and 2.0 micrograms per gram of dried rumen material when prairie hay (Ration 2), alfalfa hay (Ration 1), and sorghum silage (Ration 4) were fed, respectively.

Nicotinic acid synthesis appeared to be greater when a high-quality roughage such as alfalfa hay (Ration 2) or sorghum silage (Ration 4) was fed than when a ration which contained only concentrates was fed (Ration 6). However, pantothenic acid synthesis was the greatest when an all-concentrate ration was fed. The amounts of B vitamins synthesized in the rumen of lambs fed the all-concentrate ration (Ration 6) were nicotinic acid 91.8, riboflavin 8.3, and pantothenic acid 20.4 nicrograms per gram of dried rumen material.

There was only a small amount of B vitamin synthesis in the rumen when prairie hay was fed alone. The amounts which were synthesized in the rumen were nicotinic acid 36.9, riboflavin 2.9, and pantothenic acid -2.2 micrograms per gram of dried rumen material. The addition of corn and soybean meal to a prairie hay roughage ration (Ration 2 vs ration 6) markedly increased the amount of synthesis of the three B vitamins studied in this experiment. These findings were in agreement with those of Lardinois _et al_., (1944) who found that the addition of a readily available carbohydrate such as corn molasses or starch, and a nitrogen supplement such as urea or casein, to a ration containing timothy hay as the roughage, increased the microbiological synthesis of nicotinic acid, riboflavin, and pantothenic acid in the rumen. There appeared to be slightly more rumen synthesis of the three B vitamins studied in this experiment when soybean meal was fed (Ration 2), than when urea was fed (Ration 3).

Apparently the addition of alfalfa ash to a corn cob basal ration improves the digestibility of the organic matter in the ration (Part II of this thesis). It seemed desirable to study the effect of alfalfa ash on the synthesis of B vitamins by the microorganisms present in the rumen of lambs. The results obtained in this study indicate that B vitamin synthesis in the rumen was increased when alfalfa ash was added to the corn cob basal ration (Rations 7 and 8). The values obtained were nicotinic acid 49.6 and 68.3, riboflavin 4.7 and 6.5, and pantothenic acid 10.1 and 12.7 micrograms per gram of dried rumen material for the cob basal ration (Ration 7) and the cob basal plus alfalfa ash ration (Ration 8), respectively.

Table 7

Feeds and Rations Fed in Experiment II

Feed	Ration Number (amount fed in grams air dry basis) 1	2	3	4	5	6	7	8
Alfalfa Hay	360							
Prairie Hay		360	360			600		
Sorghum Silage				360				
Corn	420	320	422	350	720			
Soybean Meal	20	120		90	80			
Urea			18					
*Corn Cob Basal							706	
*Corn Cob Basal + Alfalfa Ash								748
Total Amount Feed per Day	800	800	800	800	800	600	706	748

* The corn cob basal ration contained 45% corn cobs, 25% corn, 20% corn gluten meal, 7% corn syrup, and 3% corn oil, plus 6 grams $CaHPO_4$ per day.

Table 8

Nicotinic acid, Riboflavin and Pantothenic Acid Content of Feeds Used in Experiment II

Feeds	Nicotinic acid microgms/gm	Riboflavin microgms/gm	Pantothenic acid microgms/gm
Alfalfa Hay	31.6	9.8	29.3
Prairie Hay	14.5	3.2	11.1
Sorghum Silage	25.4	5.0	21.1
Ground Corn Cobs	13.0	2.3	5.0
Yellow Corn	16.4	1.4	6.3
Corn Gluten Meal	43.4	2.2	5.9
Soybean Meal	21.8	2.8	13.8

Table 9

Nicotinic Acid Content of Rations Fed and Rumen Contents Collected in Experiment II

Ration	Ration No.	Sheep No.	Present in Ration Microgms/gm		Present in Rumen Contents Microgms/gm	Quantity Synthesized Microgms/gm
Alfalfa, Corn,	1	10	23.4		139.9	116.5
Soybean Meal	1	29			137.6	114.2
				Ave.	138.9	115.4
Prairie Hay, Corn	2	6	16.4		108.1	115.4
Soybean Meal	2	18			92.8	76.4
				Ave.	100.4	84.1
Prairie Hay, Corn,	3	5	15.2		77.7	62.5
Urea	3	11			90.3	75.1
				Ave.	84.0	68.8
Sorghum Silage,	4	7	21.1		151.6	130.5
Corn, Soybean	4	12			145.5	124.4
Meal				Ave.	148.6	127.5
Corn,	5	4	16.9		120.0	103.1
Soybean Meal	5	14			97.3	80.4
				Ave.	108.7	91.8
Prairie Hay	6	2	14.5		50.2	35.7
	6	23			52.5	38.0
				Ave.	51.4	36.9
Cob Basal	7	8	18.6		69.0	50.4
	7	12			67.4	48.8
				Ave.	68.2	49.6
Cob Basal	8	1	18.6		78.6	60.0
+ Alfalfa	8	13			95.2	76.6
Ash				Ave.	86.9	68.3

Table 10

Riboflavin Content of Rations Fed and Rumen Contents Collected in Experiment II

Ration	Ration No.	Sheep No.	Present in Ration Microgms/gm	Present in Rumen Contents Microgms/gm	Quantity Synthesized Microgms/gm
Alfalfa, Corn,	1	10	5.2	11.8	6.6
Soybean Meal	1	29		11.3	6.1
			Ave.	11.6	6.4
Prairie Hay, Corn,	2	6	2.4	8.7	6.3
Soybean Meal	2	18		10.0	7.6
			Ave.	9.4	7.0
Prairie Hay, Corn,	3	5	2.2	8.2	6.0
Urea	3	11		9.2	7.0
			Ave.	8.7	6.5
Sorghum Silage,	4	7	3.2	14.8	11.6
Corn, Soybean	4	12		12.0	8.8
Meal			Ave.	13.4	10.2
Corn,	5	4	1.5	8.8	7.3
Soybean Meal	5	14		10.7	9.2
			Ave.	9.8	8.3
Prairie Hay,	6	2	3.2	6.1	2.9
	6	23		6.0	2.8
			Ave.	6.1	2.9
Cob Basal	7	8	1.8	6.4	4.6
	7	12		6.5	4.7
			Ave.	6.5	4.7
Cob Basal,	8	1	1.8	7.1	5.3
+ Alfalfa Ash	8	13		9.4	7.6
			Ave.	8.3	6.5

Table 11

Pantothenic Acid Content of Rations Fed and Rumen Contents Collected in Experiment II

Ration	Ration No.	Sheep No.	Present in Ration Microgms/gm	Present in Rumen Content Microgms/gm	Quantity Synthesized Microgms/gm
Alfalfa, Corn,	1	10	16.9	20.0	3.1
Soybean Meal	1	29		24.3	7.4
			Ave.	22.2	5.3
Prairie Hay, Corn,	2	6	9.6	16.6	7.0
Soybean Meal	2	18		18.5	8.5
			Ave.	17.6	8.0
Prairie Hay, Corn,	3	5	8.3	14.6	6.3
Urea	3	11		13.8	5.5
			Ave.	14.2	5.9
Sorghum Silage,	4	7	13.8	12.0	- 1.8
Corn, Soybean Meal	4	12		20.7	6.9
			Ave.	16.4	2.6
Corn,	5	4	7.0	32.2	25.2
Soybean Meal	5	14		22.5	15.5
			Ave.	27.4	20.4
Prairie Hay	6	2	11.1	9.0	- 2.1
	6	23		8.8	- 2.3
			Ave.	8.9	- 2.2
Cob Basal	7	8	5.0	16.1	11.1
	7	12		14.0	9.0
			Ave.	15.1	10.1
Cob Basal	8	1	5.0	16.3	11.3
+ Alfalfa Ash	8	13		19.0	14.0
			Ave.	17.7	12.7

SUMMARY

Rumen contents collected from grass-fed and grain-fed cattle were analyzed for crude protein, ether extract, crude fiber, and ash. The percentage of the various nutrients present in the rumen material was found to be dependent upon the ration fed and the time of collection following the last feeding of the cattle.

A concentrate of the soluble nutrients present in the rumen material was found to contain 12 to 25 percent crude protein and 35 to 50 percent ash of a very alkaline nature. This concentrate contained considerable riboflavin and nicotinic acid, but not nearly enough for it to have much merit as a commercial source of these vitamins.

In a second experiment rumen contents were collected from lambs fed equal quantities of various rations. The rumen contents were assayed microbiologically for nicotinic acid, riboflavin, and pantothenic acid. The type of roughage fed was found to have a direct effect on the amounts of B vitamins synthesized in the rumen. An all-concentrate ration of corn and soybean meal appeared to favor pantothenic acid synthesis, while nicotinic acid synthesis appeared to be greater when a high quality roughage such as alfalfa hay or sorghum silage was included in the ration. There seemed to be very little synthesis of B vitamins when prairie hay was fed alone. The addition of corn and soybean meal to a prairie hay ration markedly increased the amount of rumen synthesis of the three B vitamins studied in this experiment.

The addition of alfalfa ash to a corn cob basal ration appeared to increase the synthesis of B vitamins by the microorganisms in the rumen of lambs.

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II. FACTORS AFFECTING THE DIGESTIBILITY OF LOW QUALITY ROUGHAGES BY LAMBS

TABLE OF CONTENTS

PART II

INTRODUCTION

Roughage materials constitute the major portion of feeds consumed by cattle and sheep in the production of meat, milk, and wool. The efficiency with which hays, pastures and other roughages are utilized by ruminants is therefore very important.

Generally speaking, there are two methods of approaching this problem. The first method involves the production of higher quality roughages of superior nutritive value. The development of modern hay- and ensilage-making equipment, along with improved techniques which have been developed through research, has simplified the production of higher quality roughages. Nevertheless, there are still large quantities of low quality roughage materials produced each year due to adverse weather conditions, lack of effort on the part of the producer, and as by-products in the production of such crops as corn, other cereals, soybeans, cotton and sugar beets.

A second method of increasing roughage utilization is to increase the efficiency with which the animal uses roughages of low quality. Ruminants are able to utilize large amounts of roughage due to the presence in the rumen of a complex microbiological population. These microorganisms are able to utilize the components of feeds, converting them into more easily digested materials which are then used by the host animal. These microorganisms require certain definite nutrients in order to digest roughages at maximum efficiency. If such nutrients are lacking or are present in limiting amounts, the efficiency of ruminal fermentation may be seriously affected. Among the important nutritional requirements are certain mineral elements. An investigation of the relation of the mineral composition of the feed to its efficiency of use by the animal, would be of value in determining more clearly the environmental factors favoring ruminal action.

This investigation was undertaken in an attempt to determine the effect of certain minerals on the digestibility of rations containing poor quality roughages. The effect of adding cerelose at different levels on the digestibility of a ration containing a poor quality roughage was also studied.

REVIEW OF LITERATURE

The following literature review is concerned primarily with digestion experiments in which the addition of various amounts and kinds of proteins, carbohydrates, and minerals to low quality roughage rations has been studied.

The Effect of Protein or Available Nitrogen

Gallup and Briggs (1948) have demonstrated that the dry matter digestibility of prairie hay increased as the protein content of the hay increased. The digestibility of each ration was determined with four or more two-year-old steers. The order of feeding was arranged in a manner which avoided feeding the same ration to more than one steer during the same collection period. The prairie hays contained different levels of protein varying from 3 to almost 6 percent. Dry matter digestibility increased from 47 percent to 60 percent for the hays containing 3.0 percent and 6.0 percent protein, respectively. The addition of cottonseed meal in amounts from 0.5 pound to 3 pounds daily to a ration of prairie hay increased the digestibility of the dry matter and crude fiber of the ration. Differences in digestibility related to the protein content of the prairie hay were again apparent.

The effect of adding urea to a basal ration of low quality prairie hay for lambs has been studied by Briggs _et al_., (1948). Eight lambs were used in each digestion trial. Five digestion trials were conducted in the first experiment. During the first trial the lambs were fed prairie hay alone. During the remaining trials the lambs received, in addition to the same feeding of hay, a nitrogen supplement of cottonseed meal or urea. The urea was fed in three different forms; a urea pellet containing hominy feed and molasses and compounded to contain a crude protein equivalent of 43.5 percent on an air-dry basis, Du Pont "Two-sixty-two" which is a special commercial peparation of urea, and crystalline urea. In all the rations, the nitrogen supplements were fed at the same protein equivalent. The apparent coefficients of digestibility for organic matter were 43.8 percent when prairie hay was fed and 52.4-55.0 percent when either of the forms of urea was substituted for cottonseed meal in the ration. In a second experiment cottonseed meal or urea pellets, containing varying amounts of urea and cottonseed meal, but compounded to be equal in crude protein content, were added to a prairie hay ration. The lambs digested 40.2 percent of the organic matter in the ration when prairie hay was fed alone and 53.0 to 54.8 percent of the ration when cottonseed meal or urea pellets were added to the prairie hay ration.

Burroughs and associates have recently studied the effect of adding soybean meal (1949a), dried skim milk (1949b), or casein (1950b), on the digestibility of the roughage dry matter by steers. In the first experiment (1950b) soybean meal was added at two different protein levels (8 and 15 percent) to rations containing either corn cobs or timothy hay as the roughage. The schedule of feeding the four rations was staggered over the four collection periods, and two series of four collection periods were completed in this manner. The apparent digestion coefficient for the roughage dry matter was calculated by difference. In order to make such a calculation these workers assumed that the concentrate constituents of the ration were digested in a constant manner regardless of the amounts included in the ration or of the type of roughage which was included in the ration. Due to the complementary and supplementary effects of feeds on the digestibility of other constituents in the ration when fed to ruminants, it appears that this procedure might be subject to considerable error (Maynard 1947). However, since this calculation was used when both the 8 and 15 percent protein rations were fed the trend obtained appears to be real. The average apparent digestion coefficient of the corn cob dry matter was calculated to be 59 percent and 67 percent for the rations containing 8 and 15 percent protein, respectively. The average apparent digestion coefficients of the timothy hay dry matter was calculated to be 51 and 59 percent for the rations containing 8 percent and 15 percent protein, respectively.

In a second very similarly conducted experiment, Burroughs and associates (1949b), studied the effect of various amounts of dried skim milk on the digestibility of the dry matter of a ration of corn cobs and corn starch. In this study the digestibility of the corn starch and dried skim milk was considered to be constant at 87.2 percent and 89.7 percent, respectively. By calculating the apparent coefficient of digestion of the corn cob dry matter, it was determined that as the protein content of the ration increased from 5.0 percent to 18.5 percent, the apparent coefficient of digestibility of corn cob dry matter increased from 48.0 percent to 62.6 percent, respectively. In a later experiment these workers (1950b) obtained similar results when casein was added at various levels to a ration of corn cobs and corn starch when fed to steers.

Watson *et al.*, (1947) conducted an experiment in which timothy hay, soybean meal, and barley were fed to cattle in various combinations and in such a manner that the nutritive ratios varied from 1:2.8 to 1:10.1. The results indicated that there was no difference in the digestibility of either total dry matter or crude fiber due to the differences in the nutritive ratio of the rations. These results appear to conflict with the results which have been previously reviewed. It should be pointed out that the timothy hay which was fed in this later study contained 8 percent protein, which is considerably more than was present in the prairie hay fed by Gallup _et al._, (1948) and in the corn cobs fed by Burroughs _et al._, (1949a, 1949b, 1950b).

Swift _et al._, (1947) have found that the addition of casein to a basal ration containing 13.2 percent protein tended to decrease the digestibility of the crude fiber of the ration.

In a series of _in vitro_ experiments, Burroughs and associates (1950a, 1950b, 1950d, 1950e, 1951a) have demonstrated that the addition of various protein supplements and urea to an "artificial rumen" increases cellulose digestion.

The Effect of Readily Available Carbohydrate

The addition of starch or molasses to the ration for a ruminant usually decreases the digestibility of the nutrients in the basal ration. This appears to be particularly noticeable in the use made of protein and crude fiber. (Armsby and Fries 1918, Briggs 1937, Lindsey 1910).

Gallup, Briggs, and Hatfield (1950) fed steers and lambs maintenance and fattening rations of prairie hay, corn and a protein supplement. The apparent digestibility of the crude fiber in the maintenance rations was about 71 percent for steers and about 65 percent for lambs, while the apparent digestibility of the crude fiber in the fattening rations was about 61 percent for steers and about 58 percent for lambs. This decrease in the apparent digestibility of the crude fiber when the fattening rations were fed was believed, by these workers, to be due to the large amounts of "readily fermentable carbohydrates" (corn) present in these rations.

Mitchell et al., (1940), in four trials with beef calves, found that the addition of glucose to rations of varying protein content, compounded from timothy hay, corn, and cottonseed meal, decreased the digestibility of crude fiber approximately 25 percent.

In a more complete experiment, Hamilton (1942) studied the effect of adding glucose to a ration compounded from timothy hay, corn and cottonseed meal on the digestibility of protein and crude fiber present in this ration. Six cross-bred ewe lambs were used in this experiment. The lambs were fed at the rate of 1.6 pounds of feed per 100 pounds live weight. Average digestion coefficients for six lambs for the basal and basal plus sugar rations, respectively, were: dry matter, 65.4 and 67.7; crude protein, 61.9 and 54.1; crude fiber, 43.8 and 31.9; ether extract, 74.3 and 73.3; and nitrogen-free extract, 76.4 and 79.7 percent. Thus, the addition of sugar to the ration caused an increase in the apparent digestibility of dry matter and nitrogen-free extract, and a decrease in the apparent digestibility of crude protein and crude fiber.

Cox (1948), in a physical balance study, conducted three digestion trials. Lambs were fed corn, cottonseed meal and either paper pulp or wood pulp, with the concentrates held constant in amount for the three lots and the pulp varied so as to give crude fiber-total digestible nutrient ratios of 1 to 3.21, 1 to 3.82 and 1 to 4.54. The digestion coefficients obtained from the lambs on this type of ration were quite variable between animals within the same lot and no definite conclusions could be drawn.

The digestibility of rations by lambs as affected by proportions of nutrients has been studied in detail by Swift et al., (1947). Fifteen Hampshire wether lambs, selected on the basis of uniformity of live weight and regularity of feed consumption, were divided into groups of five. All lambs were drenched with phenothiazine prior to being placed on experiment. Each experimental period consisted of a preliminary period of 10 days and a collection period of 10 days. Each experimental period involving the maximum amount of supplement preceded the one of lesser amount, which in turn was followed by the basal period. The object of this order was to reduce the probability of feed refusal as the experiment progressed. The basal ration consisted of mixed alfalfa-timothy hay of excellent quality, corn meal, and linseed oil meal. Supplements were added at what was referred to as maximum and one-half the maximum level. These supplemented rations were compared to the basal ration. The supplements which were studied were oat straw, starch, cerelose, casein, urea and corn oil. Due to the unpalatable nature of starch it was impossible to complete a trial when starch was added at the maximum level. The addition of oat straw at two different levels to the basal ration resulted in consistent decreases in the percentage of digestibility of dry matter, crude protein, and ether extract of the supplemented rations as compared to the basal. The addition of starch to the basal ration resulted in a definite depression in the digestion of the crude fiber and crude protein. The addition of cerelose at one-half the maximum level resulted in a significant increase in the digestibility of the dry matter of the ration with no apparent change in the protein coefficient. However, when the amount of cerelose was doubled, the percentage of protein digested was significantly less (65.4) than in the basal period (70.0). The digestibility of the crude fiber was also decreased considerably when the higher amount of cerelose was fed. The apparent percentage of digestibility was 43.3 for the basal ration plus the high level of cerelose and 50.7 for the non-supplemented basal ration. The addition of a large amount of corn oil decreased the apparent percentage of digestibility for crude fiber from 49.0 percent to 40.7 percent. The effect of casein has been previously discussed.

Burroughs and associates (1949c) conducted a series of five digestion trials with steers in a study of the effect of starch upon roughage digestiion. The methods used in this experiment were identical with those previously reviewed (Burroughs 1949a, 1949b, 1950b). The addition of starch to a basal ration of corn cobs and dried skim milk decreased the apparent percentage of digestibility of the corn-cob dry matter (determined by difference) from 57.0 percent to 34.6 percent. The addition of corn starch to a basal ration of high quality alfalfa hay apparently had little effect on the digestibility of the dry matter of the hay. In vitro studies by these workers have indicated similar results. (Arias 1951, Burroughs 1950a, Burroughs 1940d).

Hoflund et al., (1948) measured the ability of the rumen to digest cellulose by suspending cotton threads of definite length into it through a rumen fistula. The rate of cellulose digestion was measured by the breaking strength of the thread after being suspended into the rumen for a definite period of time. Using this technique as a criterian of measurement, these workers obtained results which indicated that cellulose digestion was taking place at the maximum rate when there was 0.1 - 0.2 percent sugar in the rumen with either more or less being inhibitory.

The Effect of Minerals

The reduction in the utilization of feed brought about by a phosphorus deficiency might be assumed to be due, at least in part, to a reduction in the digestibility of the ration. However, phosphorus-deficient cattle apparently digest their feed as efficiently as phosphorus supplemented cattle. Riddell et al., (1934) fed two cows on a low phorphorus ration until the cows became phosphorus deficient as measured by low blood plasma phorphorus values, depraved appetite and an unthrifty appearance. Blood plasma phosphorus values were 1.34 and 1.20 milligram percent for the two low-phosphorus cows and 8.7 milligram percent for a third cow which had received a phosphorus supplement in addition to the low-phosphorus ration. The ration fed consisted of prairie hay, dried beet pulp, molasses, blood flour, corn, and oats. Dry matter digestion coefficients for these cows were very similar, 69.6 for the control and 72.0 and 68.4 for the experimental animals.

In a similar study Kleiber et al., (1936) obtained digestion coefficients from three beef heifers which had been made phosphorus deficient and from three heifers fed the same ration supplemented with phosphorus. The ration was compounded from alfalfa hay, dried beet pulp, corn starch, casein, and corn gluten meal. The digestion coefficients obtained were similar and indicated that the phosphorus-deficient heifers digested their ration as efficiently as the control heifers.

Woodman and Evans (1930) reported the results of a digestion study with two sheep, from which it was concluded that a deficiency of calcium and phosphorus in the forage did not cause it to be digested any less efficiently.

Weber and associates (1940) studied the effect of calcium on digestibility. They fed three pairs of fattening calves on a ration of sorgo silage, cottonseed meal and corn. One calf of each pair also received calcium carbonate. The digestion coefficients which were obtained indicated that the addition of calcium to a low calcium ration fed fattening calves did not significantly increase the digestibility of this ration.

Becker and associates (1949) made lambs cobalt deficient by feeding a ration of shelled yellow corn, powdered whole milk, and cobalt-deficient grass hay. Digestion studies indicated that lambs fed supplemental cobalt digested the ether soluble and nitrogen free extract fractions of the ration more efficiently than the lambs fed the basal ration. The addition of cobalt to the ration appeared to have no effect on the digestibility of the crude fiber fraction of the ration.

Burroughs et al., (1950c) have studied the effect of alfalfa hay, a water extract from alfalfa hay, and alfalfa ash on the digestion of corn cobs by steers. Four grade Hereford steers were used in these digestion trials. In the first trial the steers were fed rations containing different ratios of alfalfa and corn cobs. A total of 5 pounds roughage, 4 pounds corn starch, 0.2 pound bone meal, and sufficient casein to maintain an approximately constant protein level in all rations was fed per steer per day. Assuming that the digestibility of starch and casein was constant regardless of the ratio of alfalfa to corn cobs, these workers calculated by difference what they referred to as the apparent coefficient of digestion of roughage dry matter. Using this procedure it was found that the apparent coefficient of digestion of roughage dry matter increased as the ratio of alfalfa hay to corn cobs increased. Then by assuming the apparent coefficient of alfalfa hay to be constant at 60.9 percent, which was the digestion coefficient obtained when this roughage was fed alone, the apparent coefficient of digestion of corn cobs was computed. The apparent digestion coefficient of corn cobs was found to increase as the ratio of alfalfa hay to corn cobs increased. In a second trial, which lasted over a period of 30 days, a water extract of alfalfa hay increased the apparent digestion coefficient of corn cob dry matter from 34.4 to 48.9 percent. In a third trial, the addition of alfalfa ash to a ration of corn cobs, starch, and dried skim milk increased the apparent digestion coefficient of the corn cob dry matter from 38.5 percent to 52.0 percent. These workers did not present data on the digestibility of the dry matter of the total ration.

Swift and associates (1951) conducted a study in which they fed lambs a ration containing about 40.4 percent corn cobs, skim milk powder, cerelose, bone meal, and salt. A little corn oil and a small quantity of timothy hay were added in order to increase the palatability of the ration. This ration was fed in a series of digestion trials with and without the addition of alfalfa ash. The sheep were fed the alfalfa ash for a period of three weeks prior to collection. A summary of the results obtained are presented in the following table.

Although the mean coefficient of digestibility of every ration constituent was increased by the addition of alfalfa ash, these workers found that only the increase in digestibility of crude fiber was statistically significant.

In an _in vitro_ study made by Meites _et al_., (1951) indirect evidence

The Effect of Alfalfa Ash on the Digestibility of a Corn Cob Basal Ration* (Swift et al., 1951)

Ration	Apparent Percentage of Digestibility					
	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	NFE %	Energy %
Basal	63.2	48.6	84.5	43.0	69.6	60.9
Basal + Alfalfa Ash	64.6	51.0	86.9	54.8	70.5	62.3

* Each figure represents 18 digestion periods on the basal ration and 22 on the basal ration plus alfalfa ash.

was obtained that neither cobalt nor iron were the minerals responsible for the beneficial effects obtained from feeding alfalfa ash. Burroughs and associates (1951b) using the "artificial rumen" technique have shown that a complex mineral mixture resembling the composition of sheep saliva with trace elements added, increased the digestion of cellulose and poor quality roughages but had little effect on good quality roughages.

Miscellaneous Factors

Grinding has been demonstrated to decrease the digestibility of hay. Forbes et al., (1925) conducted digestion experiments in which they fed steers alfalfa hay and alfalfa meal. The steers digested the dry matter of the alfalfa hay 2.2 percent more efficiently than the alfalfa meal. Bechdel et al., (1927) fed cows alfalfa hay and alfalfa meal and obtained results which indicated the cows digested the hay 2.6 percent more efficiently than the meal. Heller et al., (1941) using sheep as the experimental animals obtained results which indicated that the sheep digested the crude fiber portion of a ration containing chopped alfalfa hay as the roughage about 3 to 4 percent more efficiently than when the hay was ground into a meal before feeding.

Conrad *et al.*, (1950) conducted an experiment from which they concluded that rumen inoculation of calves increased the digestibility of the cellulose in the ration. The rumen-inoculated calves consumed less hay than the non-inoculated calves. Therefore, it seems reasonable to believe that the increased apparent digestibility of the cellulose in the ration by the inoculated calves might have been due to a lower intake of cellulose by this group.

Bell and associates (1951) have demonstrated that the daily feeding of 0.2 grams of aureomycin to mature steers decreased the digestibility of the crude fiber in the ration.

EXPERIMENTAL OBJECTIVES

Experiments were designed to study the following problems:

Experiment I — The effect of adding alfalfa ash, a complete mineral mix, and sodium and (or) potassium acetate on the digestibility of a ration containing corn cobs as the roughage;

Experiment II — The effect of adding alfalfa ash or a complete mineral mix on the digestibility of a ration containing prairie hay as the roughage;

Experiment III — The effect of adding cerelose on the digestibility of a ration of prairie hay and crude casein;

Experiment IV — The effect of adding alfalfa ash, a complete mineral mix, or synthetic alfalfa ash on the digestibility of a ration containing corn cobs as the roughage.

EXPERIMENT I

The Effect of Mineral Supplements on the Digestibility of a Corn Cob Basal Ration

In a series of digestion trials with steers Burroughs _et al._, (1950c) demonstrated that corn cob digestion was improved progressively with respective additions of alfalfa hay, a water extract of dehydrated alfalfa meal or the ash of alfalfa meal. The results obtained by these workers were interpreted as being due to the presence of inorganic nutrients in good quality alfalfa hay which are essential to rumen microorganisms involved directly in roughage digestion. Swift _et al._, (1951) also obtained evidence that alfalfa ash improved the digestion of a ration containing corn cobs. McLeod and Snell (1947, 1948) have clearly demonstrated that certain lactic-acid-producing bacteria have a definite potassium requirement and that the presence of large amounts of sodium increases the potassium requirement of these bacteria. Sirny (1951) has demonstrated that there is an antagonistic relationship between sodium and potassium in certain lactabacilli and that high sodium prevents maximum growth. Some of these organisms are facultative anaerobes, and it is known that a certain amount of lactic acid is produced in the rumen. It appears reasonable to believe that a similar relationship might exist with the rumen microorganisms. This study was conducted as a pilot experiment in an attempt to determine whether or not a potassium-ion, sodium-ion antagonism might account for the observed effects of alfalfa ash, which is high in potassium.

Experimental Procedure

Western wether lambs were used in this experiment. Two weeks prior to being placed on their respective rations, each lamb was drenched with a phenothiazine preparation in order to minimize the effect of parasitic infestation on the digestive ability and physiological state of the lamb. The lambs were fed their respective rations in individual stanchions and when not eating were allowed the freedom of a large box stall. Collection of feces was made by means of a light harness and bag similar to the type designed by Garrigus (1939). The feces were collected once daily, weighed, and aliquoted for analysis. The samples were kept in tightly sealed jars, and were refrigerated at about 4°C.

The lambs were fed the rations given in Table 1. The basal ration consisted of 45 percent ground corn cobs, 25 percent ground yellow corn, 20 percent corn gluten meal, 7 percent corn syrup and 3 percent corn oil. The syrup and oil were included in this ration in order to encourage the lambs to eat all of the otherwise unpalatable cobs. The mineral supplements used in this experiment were added to the basal ration. Mono-calcium phosphate was added to all rations in order to provide adequate amounts of calcium and phosphorus. Since this experiment was designed to study the effects of sodium and potassium on digestion, it was thought desirable to provide chloride in the rations in a form other than sodium chloride. Therefore, calcium chloride was added in order to provide chloride in the ration. Cobalt chloride, potassium iodide and A and D oil were also included in all rations. Ration 1 was considered to be the basal ration and therefore contained only those minerals previously mentioned. Ration 2 contained, in addition to the previously mentioned minerals, sodium chloride, magnesium sulfate, zinc chloride, potassium chloride, ferrous sulfate, and copper sulfate. These minerals were added in accordance with recommendations made by the National Research Council for Sheep (Pearson *et al*., 1949). Ration 3 was supplemented with alfalfa ash. The alfalfa ash was obtained by burning high quality alfalfa hay in an open tank, followed by further ashing in a muffle furnace at 600°F. The alfalfa ash was fed at a rate equivalent to that present in one pound of alfalfa hay. Ration 4 was supplemented with sodium acetate, Ration 5 with potassium acetate and Ration 6 with both sodium and potassium acetate. In Rations 4 and 6, potassium was fed at approximately the same rate as was present in the alfalfa ash obtained from one pound of alfalfa hay. The potassium and sodium were fed at equimolar concentrations.

It should be pointed out that considerable difficulty was encountered at the start of the experiment in getting the lambs to eat the ration when certain mineral combinations were included. For example, when the lambs were placed on Ration 1 they would readily eat this ration for about three days and then would go off feed and would appear ill and restless. Lambs on the other rations did not become ill and continued to eat their ration in a normal manner. It was found that when the calcium chloride was omitted from Ration 1 the lambs came back on feed and did not become ill again. When the lambs that were on Ration 4 were placed on Ration 1 (containing calcium chloride) they became ill and went off feed. They were then put back on Ration 4 and after a recovery period of about four days, they again appeared normal. However, it was noticed that Rations 1 and 2 appeared to be somewhat unpalatable. The lambs on these rations ate slower and would frequently leave part of the ration uneaten. It was found that the substitution of di-calcium phosphate for mono-calcium phosphate in these Rations (1 and 2) increased the palatability. For these reasons, in Trials 2, 3 and 5, calcium chloride was omitted from Rations 1 and 2, and di-calcium phosphate was substituted for mono-calcium phosphate. Since Rations 3, 4, 5, and 6 appeared palatable and produced no noticeable ill effects on the lambs, they were left unchanged.

The lambs were fed 636 grams of organic matter daily during Trials 1, 2, and 3. The dry matter intake varied somewhat due to small differences in the quantity of minerals fed. During Trial 4, it was necessary to feed 743 grams of organic matter daily in order for the lambs to continue to maintain their body weight. The daily amounts of minerals fed during Trial 4 were increased 14.3 percent over the amounts fed during the first three trials. Two lambs were placed on each ration during Trial 1. The various rations were fed for a preliminary period of three weeks which was followed by a ten day collection period. Following the first collection period all lambs were kept on the same rations as were fed in Trial 1 for a preliminary period of four weeks and this was followed by a second ten day collection period. Due to the difficulties encountered in getting the lambs to eat Ration 1 during Trial 1 the two sheep on this ration were removed from the experiment and 5 new lambs were started on this ration at the beginning of Trial 2. It was not necessary to remove either of the lambs on Ration 2; however, a third lamb was placed on this ration at the beginning of Trial 2. Following the second collection period the rations were switched in such a manner that no lamb was placed on the same ration which he had been fed during the previous trial. The preliminary period for Trial 3 was 8 days and the collection period was 10 days. The lambs were then left on the same rations for a three week period which was followed by a ten day collection period.

Results and Discussion

The composition of feeds used in this experiment are presented in Table 2. The complete results of this experiment are reported in Appendix Tables I through IV. The average percentage of organic matter consumed which was digested during Trials 1 through 4 is presented in Table 3. In Trial 1, the lambs fed Ration 3 (alfalfa ash) digested the organic matter in the ration about 20 percent more efficiently than the lambs on the other rations. A similar trend was noted for the other constituents of this ration. Due to difficulties in getting the lambs to eat Ration 1, it was impossible to obtain a satisfactory collection from the lambs fed this ration during the first trial. In Trial 2 the lambs fed Rations 1, 4, 5, and 6 digested the organic matter in the ration almost as efficiently as the lambs receiving the alfalfa ash (Ration 3). Some differences were noted in the various apparent coefficients of digestibility in Trials 3 and 4. However, due to the relatively large variations which occurred between the animals fed the same ration, no definite statement can be made regarding the results obtained from these trials.

At the beginning of the experiment the average weight of the lambs was 58 pounds. The lambs gained 27 pounds during the five-month experimental period.

From the limited amount of data available from these trials it appears that alfalfa ash may be beneficial to the animal, by decreasing the time required to develop a rumen microbiological population which is capable of efficiently digesting a low quality roughage ration. It also appears that the benefits derived from the alfalfa ash are not due to the presence of sodium, potassium, calcium, phosphorus, cobalt, or iodine. However, the alfalfa ash may contain minerals in more optimal ratios than in the other mineral supplements fed. The addition of small amounts of alfalfa hay to a ration consisting of large amounts of low quality roughage such as corn cobs, prairie hay, cottonseed hulls, etc. might be a practical way of increasing the utilization of these feed materials.

Table 1

Feeds and Supplements Fed to Lambs in the Corn Cob Digestion Study

Feeds and Supplements	Rations 1	2	3	4	5	6
Ground corn cobs (%)	45	45	45	45	45	45
Ground yellow corn (%)	25	25	25	25	25	25
Corn Gluten meal (%)	20	20	20	20	20	20
Corn syrup (%)	7	7	7	7	7	7
Corn oil (%)	3	3	3	3	3	3
Mono-calcium phosphate (gms.)	8.75	8.75	8.75	8.75	8.75	8.75
Calcium chloride (gms.)	5.25	5.25	5.25	5.25	5.25	5.25
*Complete mineral Mix (gms.)		9.6				
Alfalfa Ash (gms.)			35			
Sodium acetate.$3H_2O$ (gms.)				30.7		30.7
Potassium acetate (gms.)					21.9	21.9
Potassium iodide (mgms.)	0.2	0.2	0.2	0.2	0.2	0.2
Cobalt chloride (mgms.)	1	1	1	1	1	1
Cod liver oil (gms.)	1	1	1	1	1	1

* The mineral mix for Lot II consisted of: sodium chloride, 900 grams; manganese sulfate, 1.0 gram; magnesium sulfate, 300 grams; zinc chloride, 1.0 gram; potassium chloride, 200 grams; ferrous sulfate, 1.5 grams; copper sulfate, 3.5 grams.

Notes:

Calcium chloride was substituted for salt in the sodium-controlled diets to furnish chloride.
Alfalfa ash was fed at the rate equivalent to that present in 1 pound of alfalfa hay.
In Lots IV and VI, potassium was fed at the same rate as was present in the alfalfa ash in Lot III.
Sodium and potassium were fed at equimolar concentrations.
In Trials II, III, and IV, calcium chloride was not included in Rations I and II and di-calcium phosphate was substituted for mono-calcium phosphate.
For quantities of minerals fed in Trial IV multiply each figure by 8/7.

Table 2

Composition of Feeds and Basal Ration used in Corn Cob Digestion Study. (Dry Matter Basis)

Feed	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	NFE %	Ash %
Corn cobs	95.0	2.8	0.6	46.4	48.1	2.1
Corn	92.4	8.5	3.0	2.5	84.4	1.6
Corn gluten meal	92.5	44.3	1.6	4.7	46.4	3.0
Corn syrup	77.5				99.7	0.3
Corn oil	100.0		100.0			
Ration*	92.8	11.4	4.3	21.3	54.0	2.0

* This ration was fed at the rate of 636 grams of organic matter daily during Trials 1, 2, and 3 and 743 grams daily during Trial 4.

Table 3

The Effect of Various Mineral Supplements on the Digestibility of the Organic Matter in a Corn Cob Basal Ration

	Rations					
	1 Basal %	2 Basal + Com. Min. %	3 Basal + Alf. Ash %	4 Basal + Na acetate %	5 Basal + K acetate %	6 Basal + Na & K acetate %
Trial No. 1	--	52.0	72.5	55.3	54.3	52.1
Trial No. 2	72.1	69.8	75.4	73.7	74.6	75.7
Trial No. 3	74.0	74.3	74.4	76.7	77.1	73.6
Trial No. 4	72.1	69.2	73.2	81.8	77.2	73.0

EXPERIMENT II

The Effect of Mineral Supplements on the Digestibility of a Prairie Hay Basal Ration

Alfalfa ash apparently increases the digestibility of rations containing corn cobs as the roughage (Burroughs 1950c, Swift 1951). This experiment was conducted in order to determine the effect of adding alfalfa ash to a ration containing prairie hay as the roughage.

Experimental Procedure

Twelve of the lambs that were used in experiment I were used in this experiment. The lambs were selected on the basis of uniformity of live weight and regularity of feed consumption. Four lambs were placed on each ration in a randomized manner based on weight. The rations fed are presented in Table 4. The lambs were fed a basal ration containing 45 percent low quality prairie hay, 40 percent ground yellow corn, and 15 percent corn gluten meal. The hay was coarsely ground in a hammer mill in order to facilitate ease in handling. The lambs were fed 800 grams of this basal ration per day, which was equivalent to 691 grams of organic matter per day. In addition each lamb received 10 grams of di-calcium phosphate per day. The lambs fed Rations 1 and 3 were also given 5 grams of salt per day while the lambs fed Ration 2 had the salt included in the complete mineral mix. Ration 2 contained a complete mineral mix and Ration 3 contained alfalfa ash. These mineral supplements are described in Experiment I.

The methods used in conducting this experiment were essentially the same as those previously described (Experiment I). Prior to the beginning of this experiment the lambs were fed the corn cob basal ration (Ration 1 in Experiment I) for a period of two weeks in order to minimize the effect of previous rations. The lambs were then placed on their respective rations for a 7-day preliminary period, which was followed by a series of six consecutive 3-day collection periods. Consecutive 3-day collection periods were used to study the length of time required for the rumen microorganisms to become fully adapted to a change of ration if such an adjustment period existed.

Results and Discussion

The composition of the feeds and basal ration fed in this experiment are presented in Table 5. There were no feed refusals during the course of this experiment and it was possible to make complete collections from all lambs in all periods.

The apparent percentages of organic matter digested by the lambs during six consecutive 3-day collection periods are presented in Table 6. The apparent percentage of organic matter digested, as averaged from six 3-day collection periods with four lambs per ration, was 69.3 for the basal ration (Ration 1), 68.0 for the basal ration plus the complete mineral mix (Ration 2), and 70.0 for the basal ration plus alfalfa ash (Ration 3). When subjected to an analysis of variance, as outlined by Snedecor (1948), these mean differences approached significance at the 5 percent level. However, these mean differences appeared to be too small to be of any practical significance.

The first collection period was started seven days after the lambs were initially placed on their respective rations. If an adjustment period was required for the microorganisms of the rumen to become adjusted to a change in ration it apparently occurred during the 7-day preliminary period. The mean apparent percentage of digestibility of the organic matter during each 3-day collection period for lambs on the same ration was quite similar.

Since there appeared to be no definite time trend in the percentage of organic matter digested, only the samples collected during periods 1, 2, and 3 were subjected to a complete proximate analysis. The results of these analyses are given in Appendix Tables V through VII, and the averages for these three periods are given in Appendix Table VIII. There appeared to be very little difference in the apparent digestibility of the crude protein or crude fiber constituents of the three rations studied. The apparent percentages of crude protein digested, as averaged from Periods 1, 2, and 3 with four lambs per ration, were 71.4, 69.9, and 71.8, while those for crude fiber were 49.6, 47.6, and 47.6 for Rations 1, 2, and 3, respectively. It appears that the addition of minerals to a prairie hay basal ration may have actually decreased the digestibility of the crude fiber fraction of this ration. The coefficients of digestibility for ether extract were low and quite variable. However, this may be explained on the basis that the rations contained only 1.3 percent ether extract, approximately half of which was contained in the hay fraction. There was considerable variation in the digestion coefficients between periods for individual lambs. It would appear that 3-day collection periods are not long enough to obtain an accurate measure of the apparent digestibility of rations by lambs.

Under the conditions which existed in this experiment, it appeared that the addition of alfalfa ash or a complete mineral mix did not improve the apparent digestibility of a prairie hay basal ration.

TABLE 4

Feeds and Supplements Fed to Lambs in the Prairie Hay Digestion Study

Feeds and Supplements	Rations 1	2	3
Prairie Hay (%)	45	45	45
Ground Yellow Corn (%)	40	40	40
Corn Gluten Meal (%)	15	15	15
Di-calcium Phosphate (gms)	10	10	10
Sodium Chloride (gms)	5		5
Complete Mineral Mix (gms)		12	
Alfalfa Ash (gms)			40
Cod-liver Oil (gms)	1	1	1

TABLE 5

Composition of Feeds and Basal Ration Fed in the Prairie Hay Digestion Study (Dry Matter Basis)

Feeds	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	NFE %	Ash %
Prairie Hay	91.9	4.7	1.2	34.5	52.4	7.2
Yellow Corn	88.3	9.7	1.6	2.0	85.1	1.6
Corn Gluten Meal	91.4	44.3	0.7	4.3	47.5	3.2
Basal Ration	92.3	12.4	1.3	16.9	63.1	6.3

TABLE 6

The Effect of Mineral Supplements on the Digestibility of the Organic Matter in a Prairie Hay Basal Ration

Ration Identification	Ration No.	Lamb No.	Organic Matter Intake gms.	Percentage Organic Matter Digested — Collection Period Number						
				5	6	7	8	9	10	Ave. of Six 3-day Periods
Prairie Hay	1	8	691	66.9	71.6	68.1	67.3	71.8	66.5	68.7
Basal	1	16	691	63.9	69.8	73.7	66.0	64.7	63.3	66.9
	1	17	691	70.8	74.8	72.0	70.8	68.3	66.3	70.5
	1	23	691	72.6	70.8	70.5	72.3	69.4	71.6	71.2
	Ave.			68.5	71.7	71.0	69.1	68.5	66.9	69.3
Prairie Hay	2	18	691	69.1	67.5	68.9	71.5	70.2	66.3	68.9
Basal +	2	24	691	70.8	68.0	67.9	69.2	66.7	63.3	67.6
Complete	2	25	691	68.2	69.5	69.0	66.8	70.7	68.3	68.8
Mineral Mix	2	26	691	67.8	71.9	73.9	64.7	62.4	59.9	66.7
	Ave.			68.9	69.2	70.0	68.0	67.5	64.5	68.0
Prairie Hay	3	3	691	72.4	74.5	72.7	70.5	72.4	69.4	71.9
Basal +	3	6	691	66.0	68.5	70.0	68.0	71.7	66.1	68.3
Alfalfa Ash	3	19	691	66.9	69.4	70.5	69.7	69.5	69.3	69.2
	3	22	691	70.5	71.0	71.9	69.0	70.4	71.2	70.6
	Ave.			68.9	70.8	71.2	69.3	71.0	69.0	70.0

EXPERIMENT III

The Effect of Readily Available Carbohydrate on the Digestibility of a Ration of Prairie Hay and Casein

Several experiments have demonstrated that the addition of large amounts of a readily available carbohydrate, such as molasses, starch, or glucose, to a ration containing a low quality roughage decreased the apparent percentage digestibility of the crude fiber in the ration. On the other hand, certain *in vitro* studies have indicated that the addition of small amounts of a readily available carbohydrate increased the rate of cellulose digestion by rumen microorganisms. Very little research has been reported in which the effect of adding small amounts of a readily available carbohydrate on the digestibility of a low quality roughage ration was studied. This experiment was conducted in order to study the effect of adding two different levels of cerelose on the digestibility of a ration containing prairie hay as the roughage.

Experimental Procedure

The lambs that were used in Experiment II were also used in this experiment. Prior to the beginning of this experiment the lambs were fed the prairie hay basal ration (Ration I in Experiment I) for a period of two weeks in order to minimize the effect of previous rations. The lambs were then weighed and four lambs were placed on each ration in a randomized manner based on weight. All lambs were fed their respective rations for a 7-day preliminary period, which was followed by a series of three consecutive 5-day collection periods. The rations fed are presented in Table 7. Ration 1 contained 600 grams prairie hay and 60 grams of crude casein; Ration 2 contained 600 grams prairie hay, 60 grams crude casein, and 60 grams cerelose; and Ration 3 contained 600 grams of prairie hay, 60 grams of crude casein and 180 grams of cerelose. All lambs received a daily allowance of 10 grams salt, 10 grams of di-calcium phosphate and sufficient cod-liver oil to provide adequate amounts of vitamins A and D. The methods of collecting and handling feces during this experiment were the same as those previously described. (Experiment I).

Results and Discussion

The composition of the feeds and rations are presented in Table 8. Crude casein was fed in this experiment in order to provide an adequate amount of protein and yet provide a minimum of carbohydrate material such as would be provided when a protein supplement such as soybean or cottonseed meal was fed. Since the addition of a highly digestible carbohydrate such as cerelose would be expected to increase the apparent percentage digestibility of the total dry matter and nitrogen-free extract fractions of the ration, and since there was very little ether extract present in these rations, the only criteria of measurement available in this study was the effect of the addition of cerelose on the apparent percentage digestibility of the crude fiber and crude protein fractions of the ration. Each ration contained the same amount of crude protein and crude fiber.

The apparent digestion coefficients of the rations studied in this experiment for the three 5-day collection periods are given in Appendix Tables IX through XI and the average digestion coefficients for these three periods are presented in Appendix Table XII. The average digestion coefficients for the three rations studied (four lambs per ration) are presented in Table 9. The addition of cerelose to a ration of prairie hay and crude casein had no measurable effect on the apparent coefficient of digestibility of the crude fiber of the ration. The average apparent percentage of crude fiber digested was 57.3, 56.6, and 57.0 for Rations 1, 2, and 3, respectively. The apparent coefficient of digestibility for crude protein was decreased when the higher level of cerelose was fed. The average percentage of crude protein digested was 67.9, 68.7, and 63.5 for Ration 1, 2, and 3, respectively. The apparent coefficients of digestibility for organic matter and nitrogen-free extract increased as the amounts of cerelose in the ration increased. As would be expected when there is very little ether extract present in the ration, the apparent coefficients of digestibility for ether extract were quite variable.

From the results obtained in this experiment it would appear that the addition of a small quantity of readily available carbohydrate had very little effect on the utilization of a low quality roughage ration by lambs as measured by the apparent percentage of digestibility of the crude fiber contained in this ration.

TABLE 7

Rations Fed in the Carbohydrate Digestion Study (Air Dry Basis)

Feeds and Supplements	Rations 1	2	3
	gms.	gms.	gms.
Prairie Hay	600	600	600
Crude Casein	60	60	60
Cerelose	0	60	180
Salt	10	10	10
$CaHPO_4$	10	10	10
Cod Liver Oil	+	+	+
Total	680	740	860

TABLE 8

Composition of Feeds and Rations Fed in the Carbohydrate Digestion Study (Dry Matter Basis)

Feeds	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	NFE %	Ash %
Prairie Hay	92.2	4.8	1.4	36.7	50.9	6.2
Crude Casein	90.6	90.2	0	0	8.5	1.3
Cerelose	90.6	0	0	0	90.6	0
Ration						
1	92.3	12.1	1.2	32.3	45.6	8.8
2	92.2	11.1	1.1	29.8	49.9	8.1
3	91.9	9.6	1.0	25.7	56.8	7.0

TABLE 9

Average Coefficients of Digestibility of Rations Fed in the Carbohydrate Study (Dry Matter Basis)

Ration Identification	Ration No.	Dry Matter Intake	Apparent Percentage of Digestibility					
			Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
		gms.						
Prairie Hay, Casein	1	628	51.7	53.4	67.9	21.0	57.3	47.6
Prairie Hay, Casein + 60 gms. Cerelose	2	682	55.8	57.8	68.7	31.8	56.6	56.8
Prairie Hay, Casein + 180 gms. Cerelose	3	791	60.9	63.1	63.5	22.8	57.0	66.4

EXPERIMENT IV

Further Study of the Effect of Mineral Supplements on the Digestibility of a Corn Cob Basal Ration

The results which were obtained in Experiment I, using only two lambs per ration, indicated that the addition of alfalfa ash to a corn cob basal ration when fed to lambs markedly improved the digestibility of the ration during one collection period. However, during three subsequent collection periods, the first of which began one month following the initial collection period the lambs fed the corn cob basal ration digested this ration almost as well as the lambs fed the corn cob basal ration plus alfalfa ash. This experiment was conducted in order to study the effect of the addition of alfalfa ash, a complete mineral mix or a synthetic alfalfa ash on the apparent coefficient of digestibility of a corn cob basal ration.

Experimental Procedure

Twenty western wether lambs were used in this experiment. The lambs were selected on the basis of uniformity of live weight and regularity of feed consumption. The average live weight of these lambs at the beginning of this experiment was 75 pounds. Two weeks prior to the beginning of this experiment the lambs were treated for internal parasites with a phenothiazine solution. Five lambs were placed on each ration in a randomized manner based on the live weight of the lambs. Forbes et al (1946) conducted an experiment in which variations in the digestive capacity of sheep were studied. Statistical treatment of the data obtained in this experiment led these workers to conclude that, ". . . five sheep per treatment are a sufficient number for the usual purposes if the experimental technic is efficient, and the sheep have been successfully treated on account of parasites of the alimentary tract."

The rations fed in this experiment are given in Table 10. The basal ration was the same as fed in Experiment I. The lambs were fed 700 grams of this basal ration per day. In addition, all lambs received 7 grams dicalcium phosphate, 5 grams iodized salt, 0.2 milligrams cobalt chloride and 1 gram of cod liver oil per day. The lambs fed Ration 1 were limited to the previously mentioned ingredients while the lambs fed Rations 2, 3, and 4 received additional supplements in the form of a complete mineral mix, alfalfa ash, or a synthetic alfalfa ash, respectively.

The complete mineral mix and alfalfa ash supplements are described in Experiment I. The synthetic alfalfa ash represents an attempt to simulate the composition of natural alfalfa ash, particularly with respect to the content of nutritionally significant mineral elements. The analyses of alfalfa ash reported by Schrenk and Selker (1951) were used as a guide in compounding this mineral supplement, the formulation of which was as follows:

	Grams
$KHCO_3$	2350
K_2HPO_4	850
$CaCl_2$	550
$Ca(OH)_2$	1100
$MgSo_4 \cdot 7H_2O$	1600
$FeSO_4 \cdot 7H_2O$	225
$NaHCO_3$	700
$Na_2B_4O_7 \cdot 10H_2O$	100
$MnSo_4 \cdot 4H_2O$	10
$CuSo_4 \cdot 5H_2O$	70
$ZnCO_3$	6
	7561 grams

When this formula was fed at the rate of 43 grams per lamb per day it supplied approximately the same amount of the various minerals as was present in 35 grams of natural alfalfa ash. The lambs were fed their respective rations for an 8-day preliminary period, which was followed by a series of consecutive 3-day collection periods. The method of collecting and handling feces was the same as that described in experiment I.

Results and Discussion

The composition of the feeds and basal ration fed in this experiment is presented in Table 11. Lamb number 16 which was fed Ration 3 refused to eat all of his ration and had to be removed from the experiment. Consequently, collections were obtained from only four lambs which were fed Ration 3. On the night following the completion of collection period number 3, the lambs got out of the large box stall in which they were kept and had access to pasture and prairie hay over night. This necessitated a second 7-day preliminary period in order to allow time for the foreign feed to pass through the alimentary tract. Lamb number 6 refused to eat all of his ration during this second preliminary period and was removed from the experiment. The apparent percentage of organic matter digested is given in Table 12. The apparent percentage of digestibility of the organic matter obtained for lamb 6 is given for Periods 1, 2, and 3. However, these figures are not used in calculating the mean coefficient of digestibility of organic matter for Ration 4. The mean apparent percentage of organic matter digested during eight 3-day collection periods was 68.0, 68.0, 75.8, and 72.1 for the cob basal, cob basal plus complete mineral mix, cob basal plus alfalfa ash, and cob basal plus synthetic alfalfa ash rations, respectively. The addition of alfalfa ash to this corn cob basal ration increased the mean apparent digestibility of the organic matter of the ration 7.8 percentage points. The addition of synthetic alfalfa ash increased the mean apparent digestibility 4.1 percentage points, while the complete mineral mix produced no measurable effect.

The complete proximate analysis for Periods 1, 2, and 3 are presented in Appendix Tables XIII through XV and the average of these consecutive 3-day periods are presented in Appendix Table XVI. The apparent percentage of crude fiber digested during the three consecutive 2-day periods was 57.9, 63.6, 74.8, and 69.3 for the basal (Ration 1), basal plus complete mineral mix (Ration 2), basal plus alfalfa ash (Ration 3), and basal plus synthetic alfalfa ash (Ration 4) rations, respectively. The lambs which were fed the basal ration plus alfalfa ash apparently digested 16.9 percentage points more of the crude fiber fraction than the lambs fed the basal ration. The addition of synthetic ash increased the mean apparent digestibility of the crude fiber in the ration 11.4 percentage points, while the addition of the complete mineral mix caused an increase of 5.7 percentage points. The mean apparent percentage of digestibility for nitrogen-free extract was 71.1, 72.1, 76.2, and 72.2 for Rations 1 through 4, respectively. The addition of alfalfa ash to the basal ration appeared to increase the apparent digestibility of the nitrogen-free extract fraction of the ration, while the other mineral supplements produced no measurable effect. The apparent percentage of crude protein digested was 68.9, 70.8, 74.4, and 72.4 for Rations 1 through 4, respectively. The apparent coefficient of digestibility for crude protein was increased when alfalfa ash was added to the basal ration. The addition of synthetic alfalfa ash to the basal ration also appeared to increase the apparent digestibility of the crude protein fraction but to a lesser degree than the natural alfalfa ash. The apparent coefficients of digestibility for ether extract for individual lambs were quite variable and are probably of little value. The average percentage of ether extract digested was 71.0, 76.6, 81.1, 84.5 for Rations 1 through 4, respectively.

Under the conditions which existed in this experiment, it appeared that the addition of alfalfa ash to a corn cob basal ration increased the apparent digestibility of the organic matter of the ration. Although the addition of alfalfa ash increased the apparent digestibility of all fractions of the ration, the crude fiber fraction was found to be the one most affected. The addition of a synthetic alfalfa ash produced similar results but to a lesser degree than the natural alfalfa ash.

Table 10

Rations Fed in the Corn Cob Digestion Study
Experiment IV

Feeds and Supplements	Rations*			
	1	2	3	4
Ground Corn Cobs (%)	45	45	45	45
Ground Yellow Corn (%)	25	25	25	25
Corn Gluten Meal (%)	20	20	20	20
Corn Syrup (%)	7	7	7	7
Corn Oil (%)	3	3	3	3
Di-Calcium Phosphate (gms)	7	7	7	7
Sodium Chloride (gms)	5	5	5	5
Complete Mineral Mix (gms)		14		
Alfalfa Ash (gms)			35	
Synthetic Alfalfa Ash (gms)				43
Cod Liver Oil	+	+	+	+

* Fed at the rate of 628 grams of organic matter per day.

Table 11

Composition of Feeds and Rations Fed in the Corn Cob Digestion Study, Experiment IV (Dry Matter Basis)

Feeds	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	NFE %	Ash %
Corn Cobs	93.8	3.4	1.5	36.1	57.4	1.6
Corn	88.6	9.7	1.8	2.0	85.1	1.4
Corn Gluten Meal	91.2	40.2	1.5	4.3	51.3	2.7
Corn Syrup	77.5	0	0	0	97.7	0.3
Corn Oil	0	0	100.0	0	0	0
Ration						
Basal Ration	90.6	12.5	4.7	18.0	63.2	1.6

Table 12

Apparent Percentage of Organic Matter Digested in the Corn Cob Digestion Study, Experiment IV

Ration Identification	Ration No.	Lamb No.	Organic Matter Intake gms.	Apparent Percentage Organic Matter Digested — Collection Period Number 1	2	3	4	5	6	7	8	Ave. Eight 3-day Periods
Cob Basal	1	4	628	63.7	64.8	62.5	61.5	62.7	68.3	68.7	65.9	64.8
	1	17	628	69.1	71.4	70.3	69.3	68.1	65.4	86.4	68.1	71.0
	1	20	628	68.7	73.6	71.0	72.9	73.3	73.3	74.3	64.8	71.5
	1	23	628	67.1	69.2	72.9	69.6	66.6	69.7	69.7	66.9	69.0
	1	24	628	60.4	61.2	60.0	55.2	61.6	73.0	70.9	65.7	63.5
	Ave.			65.8	68.0	67.3	65.7	66.5	69.5	74.0	66.3	68.0
Cob Basal + Complete Mineral Mix	2	5	628	74.2	73.4	66.4	66.7	67.2	60.9	70.7	74.9	69.3
	2	11	628	69.5	74.5	76.7	67.7	70.2	71.5	71.7	69.0	71.4
	2	12	628	73.4	71.8	64.8	61.2	52.9	67.3	69.0	61.8	65.3
	2	19	628	66.9	68.9	68.5	69.9	59.5	52.1	67.3	67.1	65.0
	2	22	628	69.0	71.3	67.9	70.5	69.1	74.7	66.6	63.0	69.0
	Ave.			70.6	72.0	68.9	67.2	63.8	65.3	69.1	67.2	68.0
Cob Basal + Alfalfa Ash	3	1	628	76.8	78.0	84.7	63.3	75.7	78.1	77.9	76.8	76.4
	3	8	628	76.0	73.2	73.3	66.7	77.0	77.1	75.4	78.2	74.6
	3	13	628	69.2	77.7	78.7	74.0	77.2	76.4	76.0	75.1	75.6
	3	15	628	75.8	77.6	75.0	75.1	78.5	78.0	78.8	71.8	76.3
	Ave.			74.5	76.7	77.9	70.1	77.1	77.4	77.0	75.5	75.8
Cob Basal + Synthetic Alfalfa Ash	4	6	628	73.5	76.9	68.9						
	4	9	628	69.1	77.6	74.6	71.2	74.2	76.5	76.0	73.5	74.1
	4	10	628	72.0	77.5	72.6	73.2	75.1	76.2	76.1	73.1	74.5
	4	18	628	65.3	68.9	68.2	54.3	63.9	71.0	73.8	70.0	66.9
	4	26	628	71.2	77.0	75.2	75.3	63.4	76.2	75.6	68.8	72.8
	Ave.			69.4	75.5	72.7	68.5	69.2	75.0	75.4	71.4	72.1

SUMMARY

Three experiments were conducted with lambs to determine the effect of various mineral supplements on the apparent digestibility of rations containing corn cobs or prairie hay as the roughage. The mineral supplements studied were a complete mineral mix, patterned after NRC allowances for lambs; sodium and (or) potassium acetate; alfalfa ash; and a synthetic alfalfa ash. A fourth experiment was conducted to study the effect of two different levels of cerelose on the apparent digestibility of a prairie hay basal ration.

A pilot experiment, using only two lambs per ration, indicated that the addition of alfalfa ash to a corn cob basal ration when fed to lambs markedly improved the digestibility of the ration during one collection period. However, during three subsequent collection periods, the first of which began one month following the initial collection period, the lambs fed the corn cob basal ration digested this ration almost as well as the lambs fed the corn cob basal ration plus alfalfa ash. The addition of a complete mineral mix and sodium and (or) potassium acetate to a corn cob basal ration produced no measurable effect on the apparent digestibility of this ration.

In a later experiment, using 5 lambs per ration, it appeared that the addition of alfalfa ash to a corn cob basal ration increased the apparent digestibility of the organic matter of the ration. Although the addition of alfalfa ash increased the apparent digestibility of all

fractions of the ration, the crude fiber fraction was found to be the one most affected. The addition of a synthetic alfalfa ash produced similar results but to a lesser degree than the natural alfalfa ash.

The addition of alfalfa ash or a complete mineral mix apparently did not improve the digestibility of a prairie hay basal ration.

The addition of a low and high level of cerelose to a ration of prairie hay and casein, as fed to lambs, produced no measurable effect on the apparent percentage digestibility of the crude fiber fraction of this ration. However, the high level of cerelose appeared to decrease the apparent percentage digestibility of the crude protein fraction of the ration.

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APPENDIX

Table I

Apparent Digestion Coefficients of Rations
in Corn Cob Study, Trial I

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Basal +	2	16	674	336	636	50.3	50.3	48.0	51.3	50.2
Complete Mineral	2	25	674	314	636	53.7	57.6	70.8	53.9	51.4
	Ave.					52.0	54.0	59.4	52.6	50.8
Basal +	3	19	699	208	636	73.1	71.3	85.3	75.7	71.4
Alfalfa Ash	3	22	699	217	636	71.8	69.2	86.1	72.1	68.6
	Ave.					72.5	70.3	85.7	73.9	70.0
Basal + Sodium	4	17	695	347	636	49.5	47.3	64.5	50.1	48.5
Acetate	4	23	695	264	636	61.2	62.3	60.0	60.0	61.5
	Ave.					55.3	54.8	62.3	55.0	55.0
Basal + Potassium	5	18	686	336	636	52.6	44.7	66.0	58.5	50.8
Acetate	5	24	686	310	636	55.9	52.9	59.5	54.5	56.8
	Ave					54.3	48.8	62.8	56.5	53.8
Basal + Sodium and	6	15	716	281	636	60.2	54.8	55.2	61.8	61.1
Potassium Acetate	6	26	716	386	636	45.1	39.2	69.2	46.9	43.7
	Ave.					52.1	47.0	62.2	54.4	52.9

Table II

Apparent Digestion Coefficients of Rations
in Corn Cob Study, Trial II

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Basal	1	1	656	168	636	75.5	76.6	75.1	75.2	75.3
	1	5	656	174	636	74.8	73.7	69.7	76.2	75.1
	1	6	656	206	636	69.1	73.7	75.8	64.7	69.4
	1	8	656	188	636	72.2	73.6	73.4	78.2	69.4
	1	9	656	213	636	68.5	70.1	63.7	64.7	69.8
	Ave.					72.1	73.3	71.5	71.8	71.8
Basal + Complete Mineral	2	3	666	161	636	76.1	76.6	82.8	74.9	75.4
	2	16	666	236	636	64.8	69.1	67.4	60.2	65.5
	2	25	666	209	636	68.4	71.2	82.5	65.4	65.2
	Ave.					69.8	72.3	77.5	66.8	68.7
Basal + Alfalfa Ash	3	19	699	191	636	75.1	73.7	92.6	68.4	76.6
	3	22	699	185	636	75.7	74.7	88.9	77.3	74.3
	Ave.					75.4	74.2	90.8	72.9	75.5
Basal + Sodium Acetate	4	17	695	183	636	73.2	72.4	86.5	76.2	71.1
	4	23	695	177	636	74.2	73.9	86.2	79.7	71.1
	Ave.					73.7	73.3	86.4	78.0	71.1
Basal + Potassium Acetate	5	18	686	170	636	75.5	73.8	84.6	80.6	73.1
	5	24	686	180	636	73.6	72.9	86.2	71.7	73.5
	Ave.					74.6	73.4	85.4	76.2	73.3
Basal + Sodium and Potassium Acetate	6	15	716	165	636	76.2	74.6	86.5	78.5	74.8
	6	26	716	173	636	75.1	74.4	85.6	75.0	77.0
	Ave.					75.7	74.5	86.1	76.8	75.9

Table III

Apparent Digestion Coefficients of Rations
in Corn Cob Study, Trial III

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Basal	1	15	656	172	636	74.5	75.2	83.2	72.4	74.4
	1	19	656	175	636	74.1	76.1	78.8	73.4	73.3
	1	22	656	172	636	74.3	75.2	76.5	73.5	74.3
	1	26	656	180	636	73.3	73.1	77.5	76.3	74.7
	Ave.					74.0	74.9	79.0	73.9	74.2
Basal + Complete Mineral	2	17	666	156	636	76.6	76.3	87.9	76.0	75.9
	2	18	666	186	636	72.4	70.1	81.2	72.6	72.1
	2	23	666	171	636	74.3	77.5	82.9	73.4	73.0
	2	24	666	181	636	73.9	74.8	85.9	71.2	72.1
	Ave.					74.3	74.6	84.4	73.3	73.2
Basal + Alfalfa Ash	3	16	699	191	636	74.5	70.0	86.6	78.6	72.8
	3	25	699	206	636	72.2	66.3	84.9	73.9	73.4
	Ave.					73.4	68.2	85.8	76.3	73.1
Basal + Sodium Acetate	4	1	695	157	636	77.1	74.8	88.9	81.6	74.4
	4	3	695	163	636	76.2	71.5	86.2	81.1	72.2
	Ave.					76.7	73.2	87.6	81.4	73.3
Basal + Potassium Acetate	5	5	686	155	636	77.8	74.8	84.2	83.1	73.6
	5	9	686	161	636	76.4	71.5	87.6	81.3	72.3
	Ave.					77.1	73.2	85.9	82.2	73.0
Basal + Sodium and Potassium Acetate	6	6	716	170	636	74.8	70.6	84.6	78.2	71.2
	6	8	716	186	636	72.4	68.4	83.9	77.2	70.5
	Ave.					73.6	69.5	84.3	77.7	70.9

Table IV

Apparent Digestion Coefficients of Rations
in Corn Cob Study, Trial IV

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake gms.	Dry Matter Excreted gms.	Organic Matter Intake gms.	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
Basal	1	19	750	187	743	75.8	77.9	77.9	73.6	76.1
	1	26	750	245	743	68.5	78.3	66.7	65.2	68.0
	Ave.					72.1	78.1	72.3	69.4	72.1
Basal + Complete Mineral	2	17	761	228	743	70.4	69.0	71.1	69.7	71.0
	2	18	761	205	743	73.3	71.3	77.0	72.9	73.7
	2	23	761	235	743	69.2	71.7	72.9	66.9	69.4
	2	24	761	275	743	64.1	64.5	71.7	63.2	63.8
	Ave.					69.2	69.1	73.1	68.1	69.4
Basal + Alfalfa Ash	3	16	799	223	743	74.1	71.6	84.4	74.1	73.9
	3	25	799	232	743	72.3	70.9	76.7	71.2	71.8
	Ave.					73.2	71.3	80.6	72.7	72.9
Basal + Sodium Acetate	4	1*	794	127	743	83.8	84.2	84.4	84.3	83.5
	4	3	794	161	743	79.8	78.1	77.7	81.7	79.6
	Ave.					81.8	81.2	81.1	83.0	81.6
Basal + Potassium Acetate	5	5	784	185	743	76.8	75.6	82.0	79.2	75.7
	5	9	784	175	743	77.6	73.1	82.0	77.3	78.3
	Ave.					77.2	74.4	82.0	78.3	77.0
Basal + Sodium and Potassium Acetate	6	6	818	198	743	74.7	73.6	79.7	78.5	73.1
	6	8	818	225	743	71.3	72.1	74.0	70.9	71.5
	Ave.					73.0	72.9	76.9	74.3	72.3

* Lamb No 1 was partially off feed first 8 days of trial. Lamb had cleaned up by end of trial but dry matter excreted was probably low.

Table V

Apparent Digestion Coefficients of Rations in the Prairie Hay Study, Period 5

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Prairie Hay	1	8	738	264.3	691	66.9	67.7	11.8	37.4	75.6
Basal	1	16	738	286.8	691	63.9	63.3	-23.7	47.2	70.1
	1	17	738	231.4	691	70.8	70.9	7.5	51.1	77.4
	1	23	738	220.0	691	72.6	72.6	24.7	52.0	79.1
	Ave.					68.5	68.6	5.1	46.9	75.6
Prairie Hay	2	18	745	264.5	691	69.1	68.9	-4.3	48.8	75.9
Basal + Complete	2	24	745	235.9	691	70.8	74.8	16.1	47.9	77.9
Mineral Mix	2	25	745	250.5	691	68.2	63.3	10.8	49.1	75.4
	2	26	745	260.5	691	67.8	70.1	7.5	43.5	75.0
	Ave.					68.9	69.5	9.7	47.3	76.1
Prairie Hay	3	3	778	240.1	691	72.4	74.5	28.0	47.0	79.6
Basal + Alfalfa	3	6	778	288.2	691	66.0	69.4	19.4	39.4	73.4
Ash	3	19	778	260.0	691	66.9	67.7	5.4	39.4	75.2
	3	22	778	252.0	691	70.5	69.4	21.5	47.0	77.9
	Ave.					68.9	70.2	18.6	43.2	76.5

Table VI

Apparent Digestion Coefficients of Rations in
the Prairie Hay Study, Period 6

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Prairie Hay, Basal	1	8	738	225.8	691	71.6	72.4	15.1	50.0	78.3
	1	16	738	238.9	691	69.8	78.0	18.3	47.8	75.1
	1	17	738	200.6	691	74.8	74.0	26.9	57.6	80.3
	1	23	738	232.9	691	70.8	72.8	30.1	49.3	76.7
	Ave.					71.7	74.3	22.6	50.1	77.6
Prairie Hay Basal + Complete Mineral Mix	2	18	745	255.4	691	67.5	68.2	15.1	37.4	76.4
	2	24	745	254.9	691	68.0	66.3	20.4	44.3	75.5
	2	25	745	238.1	691	69.5	67.8	31.2	52.2	75.2
	2	26	745	225.1	691	71.9	76.8	39.8	51.0	77.1
	Ave.					69.2	69.8	26.6	46.2	76.1
Prairie Hay, Basal + Alfalfa Ash	3	3	778	224.9	691	74.5	77.9	49.5	55.0	79.4
	3	6	778	266.4	691	68.5	72.0	28.0	43.8	75.2
	3	19	778	260.1	691	69.4	69.6	38.7	48.0	75.7
	3	22	778	245.3	691	71.0	72.1	44.1	47.4	77.6
	Ave.					70.8	72.9	40.1	48.6	77.0

Table VII

Apparent Digestion Coefficients of Rations in the Prairie Hay Study, Period 7

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Prairie Hay	1	8	738	255.5	691	68.1	68.2	29.0	45.5	74.9
Basal	1	16	738	208.5	691	73.7	72.3	30.1	56.0	79.5
	1	17	738	224.2	691	72.0	71.3	12.9	52.5	78.4
	1	23	738	235.8	691	70.5	73.5	29.0	48.8	76.5
	Ave.					71.0	71.1	25.2	50.7	77.3
Prairie Hay	2	18	745	245.5	691	68.9	68.1	25.8	47.6	75.6
Basal + Complete	2	24	745	256.8	691	67.9	68.5	41.9	44.9	74.3
Mineral Mix	2	25	745	242.7	691	69.0	69.5	37.6	46.2	75.5
	2	26	745	212.9	691	73.9	75.9	40.9	58.1	78.3
	Ave.					70.0	70.5	36.6	49.2	75.9
Prairie Hay	3	3	778	247.2	691	72.7	75.9	49.5	52.0	77.1
Basal + Alfalfa	3	6	778	254.4	691	70.0	72.5	50.5	54.6	73.8
Ash	3	19	778	254.9	691	70.5	69.1	18.3	43.3	79.0
	3	22	778	243.1	691	71.9	71.0	29.0	54.1	77.6
	Ave.					71.2	72.1	36.8	51.0	76.9

Table VIII

Apparent Digestion Coefficients of Rations in the Prairie Hay Study, Periods 5, 6, and 7

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Prairie Hay Basal	1	8	738	248.5	691	68.9	69.4	18.6	44.3	76.3
	1	16	738	244.7	691	69.1	71.2	8.2	50.3	74.9
	1	17	738	218.7	691	72.5	72.1	15.8	53.7	78.7
	1	23	738	229.6	691	71.3	73.0	27.9	50.0	77.4
	Ave.					70.4	71.4	17.6	49.6	76.8
Prairie Hay Basal + Complete Mineral Mix	2	18	745	254.8	691	68.5	68.4	12.2	44.6	76.0
	2	24	745	249.2	691	68.9	69.9	26.2	45.7	75.9
	2	25	745	243.8	691	68.9	66.9	26.5	49.2	75.4
	2	26	745	232.8	691	71.2	74.3	29.4	50.9	76.8
	Ave.					69.4	69.9	23.6	47.6	76.0
Prairie Hay + Alfalfa Ash	3	3	778	237.4	691	73.2	76.1	42.3	51.3	78.7
	3	6	778	269.7	691	68.2	71.3	32.6	45.9	74.1
	3	19	778	258.3	691	68.9	68.8	20.8	43.6	76.6
	3	22	778	246.8	691	71.1	70.8	31.5	49.5	77.7
	Ave.					70.4	71.8	31.8	47.6	76.8

Table IX

Apparent Digestion Coefficients of Rations
in Carbohydrate Study, Trial XI

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake gms.	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
Prairie Hay,	1	17	628	52.0	53.5	67.4	45.5	57.2	47.2
Casein	1	18	628	51.9	53.2	67.7	41.6	56.4	47.4
	1	22	628	51.0	53.0	68.3	7.8	57.4	47.0
	1	23	628	54.0	55.8	69.9	10.4	60.7	49.8
	Ave.			52.2	53.8	68.4	26.3	57.9	47.8
Prairie Hay,	2	25	682	56.3	58.4	69.5	26.0	56.6	57.8
Casein + 60	2	26	682	55.9	58.0	67.4	41.6	56.9	56.9
gms. Cerelose	2	3	682	56.7	58.9	69.7	31.2	58.5	57.3
	2	6	682	53.8	55.6	67.9	26.0	54.0	54.4
	Ave.			55.7	57.7	68.6	31.2	56.5	56.6
Prairie Hay,	3	16	791	55.8	59.0	61.1	15.6	50.4	63.3
Casein + 180	3	19	791	61.0	63.1	59.4	0.0	59.3	66.5
gms. Cerelose	3	24	791	57.5	60.0	58.3	1.3	56.1	62.9
	3	8	791	62.7	65.0	61.9	23.4	61.2	67.9
	Ave.			59.2	61.8	60.1	10.1	56.7	65.2

Table X

Apparent Digestion Coefficients of Rations
in Carbohydrate Study, Trial XII

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.						
Prairie Hay, Casein	1	17	628	51.5	53.1	67.8	5.2	56.6	46.7
	1	18	628	50.9	52.3	67.8	19.5	55.7	46.6
	1	22	628	53.6	55.2	70.7	31.2	58.1	49.7
	1	23	628	51.8	53.6	69.7	28.6	57.8	46.9
	Ave.			51.9	53.5	69.0	21.1	57.0	47.4
Prairie Hay, Casein + 60 gms. Cerelose	2	25	682	54.2	56.3	69.1	14.3	55.1	55.1
	2	26	682	54.2	56.6	67.0	14.3	55.7	55.8
	2	3	682	56.3	58.5	69.0	18.2	56.4	58.5
	2	6	682	57.1	58.8	71.4	23.4	58.7	56.9
	Ave.			55.5	57.6	69.1	17.5	56.4	56.6
Prairie Hay, Casein + 180 gms. Cerelose	3	16	791	56.8	58.9	65.3	15.6	57.9	59.0
	3	19	791	62.9	65.1	65.6	27.3	57.9	68.9
	3	24	791	59.5	61.6	62.4	20.8	53.5	65.9
	3	8	791	64.3	66.3	63.1	15.6	59.4	70.9
	Ave.			60.9	64.0	64.1	19.8	57.1	66.2

Table XI

Apparent Digestion Coefficients of Rations
in Carbohydrate Study, Trial XIII

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.						
Prairie Hay,	1	17	628	46.0	48.0	62.8	11.7	51.5	42.6
Casein	1	18	628	49.3	51.1	64.3	5.2	55.8	45.5
	1	22	628	56.0	57.7	70.5	20.8	62.1	52.2
	1	23	628	53.7	55.2	68.0	24.7	58.0	50.6
	Ave.			51.2	53.0	66.4	15.6	56.8	47.7
Prairie Hay,	2	25	682	56.0	58.3	68.7	37.7	56.6	57.5
Casein + 60	2	26	682	57.0	59.1	68.2	31.2	58.1	58.4
gms. Cerelose	2	3	682	55.2	57.3	66.9	68.9	56.9	55.2
	2	6	682	56.5	58.2	69.8	39.0	55.9	57.4
	Ave.			56.2	58.2	68.4	44.2	56.8	57.1
Prairie Hay,	3	16	791	64.1	65.9	71.9	26.0	59.5	68.6
Casein + 180	3	19	791	62.3	64.4	66.6	33.8	58.7	67.2
gms. Cerelose	3	24	791	61.0	63.2	63.9	36.4	54.2	67.6
	3	8	791	62.6	64.7	62.9	57.2	56.9	68.7
	Ave.			62.5	64.6	66.3	38.3	57.3	68.0

Table XII

Apparent Digestion Coefficients of Rations in Carbohydrate Study
Average of Trials XI, XII, and XIII

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Apparent Percentage of Digestibility					
				Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.						
Prairie Hay,	1	17	628	49.8	51.5	66.0	20.8	55.4	45.5
Casein	1	18	628	50.7	52.2	66.6	22.1	55.9	46.5
	1	22	628	53.5	55.3	69.8	19.9	59.2	49.6
	1	23	628	53.1	54.8	69.2	21.2	58.9	49.1
	Ave.			51.7	53.4	67.9	21.0	57.3	47.6
Prairie Hay,	2	25	682	55.5	57.7	69.1	29.3	56.1	56.8
Casein + 60	2	26	682	55.7	57.9	67.5	29.0	56.9	57.0
gms. Cerelose	2	3	682	56.1	58.2	68.5	39.4	57.2	57.0
	2	6	682	55.8	57.5	69.7	29.5	56.2	56.2
	Ave.			55.8	57.8	68.7	31.8	56.6	56.8
Prairie Hay,	3	16	791	58.9	61.3	66.1	19.1	55.9	63.6
Casein + 180	3	19	791	62.1	64.2	63.8	20.4	58.6	67.5
gms. Cerelose	3	24	791	59.3	61.6	61.5	19.5	54.6	65.5
	3	8	791	63.2	65.3	62.6	32.1	59.1	69.2
	Ave.			60.9	63.1	63.5	22.8	57.0	66.4

Table XIII

Apparent Digestion Coefficients of Rations in Corn Cob Study, Experiment IV (Dry Matter Basis)

Period 1

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Cob Basal	1	4	651	240	628	63.7	67.0	71.0	46.3	67.5
	1	17	651	207	628	69.1	68.4	67.7	62.2	71.3
	1	20	651	209	628	68.7	68.9	56.0	63.7	71.1
	1	23	651	217	628	67.1	70.4	74.0	61.7	67.6
	1	24	651	261	628	60.4	67.8	64.4	47.3	62.5
	Ave.					65.8	68.5	66.6	56.2	68.0
Cob Basal + Complete Mineral Mix	2	5	660	175	628	74.2	75.8	79.0	63.5	76.6
	2	11	660	208	628	69.5	69.0	80.7	70.9	68.4
	2	12	660	179	628	73.4	71.6	76.7	70.6	74.4
	2	19	660	220	628	66.9	69.5	62.7	60.0	68.8
	2	22	660	204	628	69.0	72.0	74.0	63.3	69.8
	Ave.					70.6	71.6	74.6	65.7	71.6
Cob Basal + Alfalfa Ash	3	1	686	174	628	76.8	74.5	87.7	69.7	78.4
	3	8	686	178	628	76.0	73.7	82.3	75.6	76.1
	3	13	686	221	628	69.2	72.6	80.0	69.5	67.8
	3	15	686	177	628	75.8	75.5	86.3	78.8	74.1
	Ave.					74.5	74.1	84.1	73.4	74.1
Cob Basal + Synthetic Alfalfa Ash	4	6	690	184	628	73.5	73.5	84.7	68.2	74.3
	4	9	690	213	628	69.1	71.5	83.0	73.5	66.4
	4	10	690	194	628	72.0	74.0	87.0	70.4	70.9
	4	18	690	236	628	65.3	66.7	80.3	59.6	65.6
	4	26	690	199	628	71.2	70.4	79.3	66.8	72.2
	Ave.					70.2	71.2	82.9	67.7	69.9

Table XIV

Apparent Digestion Coefficients of Rations in Corn Cob Study, Experiment IV (Dry Matter Basis)

Period 2

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake gms.	Dry Matter Excreted gms.	Organic Matter Intake gms.	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
Cob Basal	1	4	651	233	628	64.8	66.5	72.7	69.2	62.6
	1	17	651	191	628	71.4	74.3	77.0	63.1	72.9
	1	20	651	176	628	73.6	72.5	76.0	68.4	75.1
	1	23	651	203	628	69.2	69.0	80.3	59.9	71.2
	1	24	651	261	628	61.2	65.8	71.3	46.0	63.9
	Ave.					68.0	69.6	75.5	61.3	69.1
Cob Basal + Complete Mineral Mix	2	5	660	180	628	73.4	72.5	78.3	73.1	73.3
	2	11	660	171	628	74.5	75.0	80.7	68.8	75.6
	2	12	660	190	628	71.8	72.8	79.7	64.5	73.2
	2	19	660	204	628	68.9	68.4	83.7	60.4	72.2
	2	22	660	189	628	71.3	72.1	83.0	64.9	72.2
	Ave.					72.0	72.2	81.1	66.3	73.3
Cob Basal + Alfalfa Ash	3	1	686	168	628	78.0	74.1	85.3	76.5	78.7
	3	8	686	192	628	73.2	71.3	82.7	75.5	77.2
	3	13	686	168	628	77.7	74.1	90.3	64.5	73.2
	3	15	686	165	628	77.6	74.9	88.0	78.2	77.3
	Ave.					76.7	73.6	86.6	74.4	76.6
Cob Basal + Synthetic Alfalfa Ash	4	6	690	164	628	76.9	73.5	89.0	75.5	77.2
	4	9	690	168	628	77.6	76.5	90.3	77.0	77.1
	4	10	690	157	628	77.5	77.3	91.0	73.9	77.7
	4	18	690	215	628	68.9	70.1	83.7	59.9	70.3
	4	26	690	163	628	77.0	73.8	88.7	78.4	76.5
	Ave					75.6	74.2	88.5	72.9	75.8

Table XV

Apparent Digestion Coefficients of Rations in Corn Cob Digestion Study, Experiment IV (Dry Matter Basis)

Period 3

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility: Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Cob Basal	1	4	651	248	628	62.5	63.4	72.7	50.6	65.1
	1	17	651	200	628	70.3	71.0	67.3	59.3	73.5
	1	20	651	195	628	71.0	69.3	68.6	66.8	72.8
	1	23	651	187	628	72.9	73.9	82.7	59.8	75.8
	1	24	651	269	628	60.0	65.0	65.0	44.4	63.2
	Ave.					67.3	68.5	71.3	56.2	70.1
Cob Basal + Complete Mineral Mix	2	5	660	226	628	66.4	65.4	73.0	51.7	70.4
	2	11	660	157	628	76.7	76.0	79.0	76.3	76.9
	2	12	660	238	628	64.8	67.0	63.7	52.9	68.0
	2	19	660	210	628	68.5	66.6	71.3	54.0	72.8
	2	22	660	212	628	67.9	68.8	83.7	58.4	69.3
	Ave.					68.9	68.8	74.1	58.7	71.5
Cob Basal + Alfalfa Ash	3	1	686	117	628	84.7	83.4	91.6	84.0	84.7
	3	8	686	204	628	73.3	72.5	91.0	71.8	72.6
	3	13	686	166	628	78.7	74.3	84.0	78.4	79.3
	3	15	686	190	628	75.0	72.0	84.0	75.2	75.0
	Ave.					77.9	75.6	87.6	77.4	77.9
Cob Basal + Synthetic Alfalfa Ash	4	6	690	221	690	68.9	64.4	87.3	66.8	69.0
	4	9	690	180	690	74.6	72.8	82.0	72.8	75.0
	4	10	690	194	690	72.6	69.8	83.3	70.6	73.0
	4	18	690	208	690	68.2	70.1	71.7	52.3	72.5
	4	26	690	176	690	75.2	72.2	86.7	74.3	75.2
	Ave.					71.9	69.9	82.2	67.4	72.9

Table XVI

Apparent Digestion Coefficients of Rations in the Corn Cob Digestion Study, Experiment IV (Dry Matter Basis)

Average Periods 1, 2, and 3

Ration Identification	Ration No.	Lamb No.	Dry Matter Intake	Dry Matter Excreted	Organic Matter Intake	Apparent Percentage of Digestibility				
						Organic Matter	Crude Protein	Ether Extract	Crude Fiber	NFE
			gms.	gms.	gms.					
Cob Basal	1	4	651	240	628	64.9	65.6	72.1	55.4	65.1
	1	17	651	199	628	70.3	71.2	70.7	61.5	72.6
	1	20	651	193	628	71.1	70.2	66.9	66.3	73.0
	1	23	651	202	628	69.7	71.1	79.0	60.5	71.5
	1	24	651	264	628	60.5	66.2	66.9	45.9	63.2
	Ave.					67.3	68.9	71.1	57.9	71.1
Cob Basal + Complete Mineral Mix	2	5	660	194	628	70.1	71.2	76.8	62.8	73.4
	2	11	660	179	628	73.6	73.3	80.1	72.0	73.6
	2	12	660	202	628	70.0	70.5	73.4	62.7	71.9
	2	19	660	211	628	68.1	68.2	72.6	58.1	71.3
	2	22	660	202	628	69.4	71.0	80.2	62.2	70.4
	Ave.					70.2	70.8	76.6	63.6	72.1
Cob Basal + Alfalfa Ash	3	1	686	153	628	79.8	77.3	88.2	76.7	80.6
	3	8	686	191	628	74.2	72.5	85.3	74.3	75.3
	3	13	686	185	628	75.2	73.7	84.8	70.8	73.4
	3	15	686	177	628	76.1	74.1	66.1	77.4	75.5
	Ave.					76.3	74.4	81.1	74.8	76.2
Cob Basal + Synthetic Alfalfa Ash	4	6	690	190	628	73.1	73.8	87.0	70.2	73.5
	4	9	690	187	628	73.8	73.6	85.1	74.4	72.8
	4	10	690	182	628	74.0	73.7	87.1	71.6	70.5
	4	18	690	220	628	67.5	69.0	78.6	57.3	69.5
	4	26	690	179	628	74.5	72.1	84.9	73.2	74.6
	Ave.					72.6	72.4	84.5	69.3	72.2

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