FACTORS AFFECTING DIGESTIBILITY AND UTILIZATION OF LOW QUALITY ROUGHAGES BY SHEEP

by

JOHN K. WARD

Bachelor of Science

Kansas State College

Manhattan, Kansas

1954

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1956

FACTORS AFFECTING DIGESTIBILITY AND UTILIZATION

OF LOW QUALITY ROUGHAGES BY SHEEP

Thesis Approved:

Allen D. Tillman
Thesis Adviser

Glen Bratcher
Head of partment

Robert MacVicar
Dean of the Graduate School

ACKNOWLEDGMENT

The writer wishes to express his appreciation to Dr. A. D. Tillman, Animal Husbandry Department, for his assistance in the planning, directing, and summarization of this study and for his aid in the preparation of the manuscript.

Grateful acknowledgment is also extended to Dr. R. J. Sirny, Agricultural Chemistry Department, for compounding the mineral combinations used and to Dr. V. G. Heller, Agricultural Chemistry Department, for directing the chemical analysis.

TABLE OF CONTENTS

Page

INTRODUCTION 1

REVIEW OF LITERATURE 2

A. Digestibility and Utilization of Low Quality Roughages as Influenced by Their Mineral Composition 2
B. Utilization of Cottonseed Hulls Fed Singly or with Supplements 6
C. Supplementation and Utilization of Corncobs 8
D. Utilization of Dietary Fat and Its Effect on the Digestibility of Other Ration Components 10

EXPERIMENT I: INDIVIDUAL VERSUS GROUP FEEDING 13

EXPERIMENT II: THE EFFECT OF MINERAL ADDITIVES ON THE UTILIZATION OF SEMI-PURIFIED AND PRACTICAL-TYPE RATIONS 16

Trial 1: Semi-purified Diet plus Mineral Additives . . . 16
Trial 2: Fattening Ration plus Mineral Additives 21

EXPERIMENT III: THE EFFECT OF FAT UPON LOW QUALITY ROUGHAGE UTILIZATION 24

Part A - Growth 24
Trial 1: Soybean Protein Semi-purified Diet plus Corn Oil and/or Alfalfa Ash 24
Trial 2: Fattening Ration plus Corn Oil and/or Alfalfa Meal or Alfalfa Ash 26
Part B - Digestibility 28
Trial 1: Effect of Corn Oil and/or Alfalfa Ash on Digestibility of a Semi-purified Diet 28
Trial 2: Effect of Corn Oil and/or Alfalfa Ash on Digestibility of a Semi-purified Diet High in Low Quality Roughage 34
Trial 3: Effect of Corn Oil and/or Alfalfa Ash on Digestibility of Ration Containing Ground Corncobs as Roughage 41

LITERATURE CITED 47

APPENDIX 52

INTRODUCTION

The digestibility and utilization of low quality roughages by ruminant animals have been studied extensively during the past 65 years. Recent work has stressed the mineral composition and deficiencies of certain low quality roughages. In order to efficiently utilize low quality roughages as a source of energy, it is necessary to properly nourish rumen microorganisms which break down cellulose into forms usable by the host animal. It has been demonstrated that the microbial population of the rumen can be increased by supplementation of low quality roughage rations with certain mineral combinations with a subsequent increase in the utilization of low quality roughages.

Since low quality roughages are bulky in nature and of relatively low value, the problem becomes one of economics as well as nutrition. It is necessary to utilize low quality roughages without extensive processing or transportation costs. The utilization of these feeds is thus of primary importance, with any means of increasing their value of vital concern to livestock producers.

This investigation was designed to measure the effects of mineral combinations and/or corn oil upon the digestibility and utilization of rations containing cottonseed hulls or ground corncobs as roughage.

REVIEW OF LITERATURE

Digestibility and Utilization of Low Quality Roughages as Influenced by Their Mineral Composition

The efficiency with which the cellulose from low quality roughages is utilized by cattle and sheep is primarily dependent upon the degree of lignification in the plant tissues and the maximal activity of rumen microorganisms which break down cellulose into forms which can be utilized by the host animal (Crampton and Maynard, 1938). Conditions necessary for optimum activity of the rumen microflora have been shown by Burroughs _et al._ (1951) to include: (1) energy, (2) available nitrogen, and (3) minerals. Forbes _et al._ (1943) demonstrated that the digestibility of various feedstuffs is influenced by the associative effects of different feed combinations and their effect upon the activity of the rumen microflora as measured by digestibility and metabolizable energy. In nourishing the rumen microorganisms the trace minerals which are required for specific physiological functions in the animal body and thus are essential dietary ingredients include iron, copper, cobalt, manganese, iodine, and zinc (Phillips, 1952). It has been found necessary to supplement crops grown on soils deficient in the previously mentioned trace minerals in order that they can be efficiently used as animal feeds.

The mineral content of some cattle feeds used in North Central Kansas was determined by Glendening _et al._ (1952) with composition of alfalfa and prairie hay on a moisture-free basis as follows:

Mineral	Alfalfa %	Prairie Hay %
Na	0.083	0.014
K	2.26	0.78
Cl	0.444	0.136
Ca	1.32	0.32
Mg	0.45	0.30
P	0.43	0.15
Fe	0.021	0.012
SO_4		0.03
	PPM	PPM
Cu	28.0	25.0
Co	0.21	0.17
Mn	48.0	53.0
Mo	0.9	1.0

Typical beef rations for the designated area were not deficient in copper, manganese or cobalt.

In studying utilization of a mineral-deficient herbage by sheep, Woodman and Evans (1930) concluded that malnutrition on such a diet was due to the failure of the diet to supply the necessary inorganic materials for structural purposes and for the normal balance of minerals in the blood and tissues of the animal's body.

Ruminant rations are commonly composed of concentrates of plant origin which are notably low in calcium and hays or fodders as roughage which are in most instances low in phosphorus (Corrie, 1951). Riddell et al. (1934) and Kleiber et al. (1936) working with cattle found that a phosphorus deficiency had no apparent effect on digestibility of ration components but that a decrease in appetite was apparent. Kleiber and co-workers also reported a decrease in efficiency of energy utilization and of food protein for the sparing of body protein. Lofgreen and Kleiber (1953) studied the availability of phosphorus in alfalfa hay by the use of radio-active phosphorus and found the apparent digestibility to be 22% and the true digestibility 91%, indicating that phosphorus in alfalfa hay is readily available for absorption by lambs.

The addition of ground limestone to a calcium-deficient fattening-type ration for cattle by Weber et al. (1940) gave increased gains and improved feed utilization; however, beneficial effects were not significant for either digestibility or appetite.

Burroughs et al. (1949) working with the artificial rumen found that good quality roughages were digested efficiently without supplementation but that poor quality roughages were not digested efficiently without the addition of a complex mineral mixture or an auto-claved water extract of cow manure. Further in vitro work by Burroughs et al. (1950a) showed that supplementation of poor quality roughages such as corn stover, wheat straw, corncobs and mature timothy-bluegrass with an auto-claved extract of cow manure or a complex mineral mixture improved the digestibility of cellulose but had no effect upon clover, rye or alfalfa hays. Work by Burroughs et al. (1951) in which ash of molasses, immature clover hay or mature timothy was added to an artificial rumen indicated that the ashes were comparable on a weight basis in stimulating cellulose digestion. The addition of auto-claved rumen juice to an artificial rumen increased cellulose digestibility two to three times (Bentley et al. 1953). They found that the effect could be simulated by the addition of nine B-vitamins, adenine, uracil, xanthine and alfalfa or molasses ash. A combination of B-vitamins and alfalfa ash appeared to be responsible for most of the increase in digestibility.

Alfalfa ash and a mineral mixture composed of copper, cobalt, manganese, zinc and iron improved average daily gain of steers on a semi-purified corncob roughage-type ration, with gains increased from 1.34 to

1.92 lb per day (Bentley and Moxon, 1952). They also found that lots receiving alfalfa ash or the mineral mixture had an increased feed consumption of approximately 25% but apparent digestibility was not affected.

Results of three trials (Bennett, 1955) indicate that there may be some basis for replacing part of the cottonseed meal in a steer fattening ration, containing sorghum silage as roughage, with alfalfa hay or dehydrated alfalfa meal. The addition of alfalfa ash to the basal ration had no apparent effect.

Tillman et al. (1954a) fed a ration containing coarsely ground prairie hay as roughage to sheep and found that neither alfalfa ash nor a complete mineral mixture would improve the apparent digestibility of the ration or any of its proximate components.

A wheat straw ration for beef calves was supplemented with dehydrated alfalfa meal pellets with a slight increase in daily rate of gain and feed efficiency resulting (Richardson et al., 1953). Tillman and MacVicar (1955) added alfalfa ash to a semi-purified ration containing wheat straw as roughage and reported slight but not significant increases in organic matter and crude fiber digestibility.

Shrewsbury et al. (1943) concluded that protein and energy could be eliminated as sole causative factors in the improvement found upon the addition of alfalfa to rations for breeding ewes, since pressed juice of alfalfa also gave favorable results.

Bryant and Burkey (1953) found bacterial flora to be more complex when dairy cows were fed alfalfa than when concentrates or wheat straw constituted the major portion of the ration.

Efficient utilization of low quality roughages may necessitate the addition of trace minerals or a complex mineral mixture to rations containing roughages grown in mineral deficient soil or to rations which are low in total ash content.

Utilization of Cottonseed Hulls Fed Singly or with Supplements

In recent years experiments have shown that properly supplemented low quality roughages such as cottonseed hulls can be used to good advantage in feeding cattle or sheep (Moore, 1951). As a result of these experiments the demand for cottonseed hulls has in most areas exceeded the available supply.

Early work on digestibility of cottonseed hulls was conducted by Emery and Kilgore (1891), Emery et al. (1891) and Emery and Kilgore (1892). In an extensive series of experiments with beef cattle Emery and co-workers tested the digestibility of cottonseed hulls alone, the effect upon digestibility when cottonseed meal was added to the ration, and the value of a cottonseed hull-cottonseed meal ration for beef production. They found that substantial increases in digestion coefficients could be achieved by the addition of cottonseed meal to a cottonseed hull ration with dry matter digestibility increased from 35.9 to 44.9%, crude protein from 24.6 to 44.3% and crude fiber from 27.1 to 33.9%. Their results clearly indicate that cottonseed hulls alone do not constitute a nutritionally adequate ration and that additional protein will correct at least a portion of the nutritional deficiencies. Digestion studies by Fraps (1914) gave slightly higher digestion coefficients than those obtained by Emery and co-workers; however, Fraps supplemented his ration with alfalfa and cottonseed meal with later work showing that digestibility can be increased through additions of alfalfa hay, alfalfa ash or extracts of alfalfa hay.

In an attempt to correlate digestibility with chemical composition Hussain et al. (1951) compared cottonseed hulls and wheat straw. They reported digestion coefficients as follows:

	Dry Matter	Crude Protein	Ether Extract	NFE	Crude Fiber
Cottonseed hulls	49.4	8.7	68.0	57.0	44.5
Wheat straw	48.7	negative	35.6	52.5	61.5

Similarities are apparent in the two roughages except for the ash content which in the case of wheat straw was 9.4% as compared to 3.4% for cottonseed hulls.

Further comparisons of cottonseed hulls to common low quality roughages were made by Starkey and Godbey (1937) in which they supplemented a steer fattening ration, using corncobs and cottonseed hulls as roughage, with cottonseed meal and found the hull-fed steers to gain 0.85 lb more per head per day. Steers fed a ration of cottonseed hulls plus alfalfa hay outgained those fed ground cotton stalks or ground gin trash plus alfalfa hay (Melton et al., 1950).

Forbes and Garrigus (1949) compared the digestibilities of two lamb rations which were similar in proximate composition except that one contained alfalfa as roughage and the other cottonseed hulls. They found that lambs fed the ration containing hulls digested 91% as much dry matter, 82% as much protein, 117% as much fat, 92% as much NFE, and 93% as much energy as did those fed the ration containing alfalfa as roughage. Of the digestible energy, both rations were 85% metabolizable.

Tillman et al. (1954b) found that alfalfa ash when added to a semi-purified diet for sheep which contained cottonseed hulls as roughage, increased the digestibility of all ration components. A synthetic alfalfa ash mixture was found to be equally effective in increasing digestibility and utilization of cottonseed hulls. Attempts to show specific mineral deficiencies for sheep in cottonseed hulls by eliminating individual minerals from synthetic alfalfa ash revealed that deletion of manganese or magnesium had little effect but that omitting copper or iron would result in significantly lower daily gains (Tefft, 1954).

Reported data indicate that cottonseed hulls can be efficiently utilized by cattle or sheep if adequate protein and a complex mineral mixture or source of minerals are provided.

Supplementation and Utilization of Corncobs

The nutritive value of corncobs fed singly and supplemented or fed as ground ear corn with supplement has not been accurately determined. Feed lot results vary from zero to values about equal to that of legume hay or corn itself (Otis, 1904; Mumford, 1905; Allison, 1917; Vaughan, 1927; Gerlaugh, 1928; Peters, 1933; Thalman and Cathcart, 1934; Gerlaugh and Rogers, 1936; and King, 1938, 1940). Digestion trials with sheep and goats conducted by Lindsey et al. (1917), Emery and Kilgore (1894) and Fraps (1924) indicate that corncobs have a total digestible nutrient value of about 46.2%, which is a value approaching that of hays. Burroughs et al. (1945) obtained a total digestible nutrient figure of 51.6% in digestion trials with beef cattle and 64% in feed lot tests. The addition of corncobs to a lamb fattening ration lowered gains due to decreased intake of feeds high in total digestible nutrients (Bell, 1949).

The value of adding minerals to a steer fattening ration composed of corn-and-cob meal plus soybean meal was demonstrated as follows by Bentley and Klosterman (1953):

Ration	Daily Gain (lb)	Corn-and-Cob Meal/CWT of Gain (lb)
Basal	1.31	612
Basal plus iron	1.26	613
Basal plus trace minerals	1.96	523
Basal plus alfalfa ash	1.89	547

The apparent coefficient of digestibility of organic matter in a ration containing corncobs as roughage which was fed to cattle was found to increase from about 35% to about 50% when alfalfa ash or a water extract of alfalfa ash was added to the ration (Burroughs et al., 1948). Similar results were obtained by Chappel (1952) in showing a 20% increase in digestibility of organic matter of corncobs with sheep when alfalfa ash was added to the ration. In further work Chappel (1952) found that the addition of alfalfa ash increased the digestibility of all ration components, especially crude fiber. Swift et al. (1951) found increased crude fiber digestibility (43.0 to 53.8%) when alfalfa ash was added to a ration containing corncobs as the roughage for sheep. Burroughs et al. (1950b) working with steers receiving a corncob ration found that alfalfa ash increased digestibility of dry matter from 38.5 to 52.0%

Beeson and Perry (1952) observed that the addition of one and two lb of alfalfa meal to a steer fattening ration containing corncobs as roughage increased daily gains by 0.13 and 0.27 lb respectively.

Daily gains of cattle on a fattening ration receiving corncobs as the only roughage were significantly increased by the addition of ash of dehydrated alfalfa meal, the ash of molasses fermentation solubles or a trace mineral supplement (Klosterman et al., 1953).

Data reported by Becker and Smith (1949) showed that the addition of cobalt to a ration containing low quality roughage increased the digestibility of ether extract and NFE.

The digestibility of rations containing corncobs as roughage has been significantly increased by the addition of alfalfa ash. This is in accordance with data reported on other low quality, low-ash type roughages.

Utilization of Dietary Fat and Its Effect on the Digestibility of Other Ration Components

Fat in the form of lard and tallow became an agricultural surplus about 1947, and since that time the animal industry has sought ways to incorporate these high energy compounds into livestock feeds in such a manner that the animals consuming the feeds could make economical and efficient use of these products. Since one lb of fat is equal to about 2.25 lb of carbohydrate on a calorific basis, it becomes readily apparent that the 700 million lb annual surplus is a potential and competitive source of a high energy feed ingredient of great economic value (Ewell, 1953).

The effect of dietary fat upon digestibility of other ration components was studied by Lucas and Loosli (1944). They found lowered digestibility of dry matter, NFE and crude fiber in rations for dairy cattle in which ether extract had been increased to 7% by the addition of corn or soybean oil. Byers et al. (1949) found that a ration of alfalfa hay and ground soybeans containing 5.2% dietary fat did not increase milk production in dairy cows when compared to a ration of alfalfa hay and soybean meal containing 2.7% dietary fat. Absorption of dietary fat was demonstrated by Allen (1934) who recovered 10 to 20% of added dietary fat in milk of dairy cows. Feeding tests involving dairy calves indicated that calves fed butterfat at the 3.5% level excelled in all respects those fed lard, tallow, corn oil, cottonseed oil and soybean oil at the same rate (Gullickson et al., 1942). Dairy calves fed hydrogenated soybean oil at the 3% level exhibited growth comparable to those fed whole milk, while calves fed two to three percent crude expeller soybean oil showed poor growth and a high mortality rate (Jacobson et al., 1949).

The utilization of energy and protein in isocaloric rations containing 3, 4, 5, 6, 7 and 8% ether extract and equal protein was found to be about the same when fed to sheep (Swift et al., 1948).

Using lambs to study digestibility as affected by proportion of nutrients and using corn oil to vary ether extract, Swift et al. (1947) fed rations containing 9.8, 6.4, and 2.8% ether extract and reported dry matter digestibility as 72.8, 76.2, and 74.7%, respectively, for the three rations. Brooks et al. (1954) found that the addition of corn oil to a sheep ration containing cottonseed hulls as roughage significantly decreased cellulose digestibility and that lard exhibited similar effects but to a lesser degree.

Results of a steer fattening trial using crude cottonseed oil to increase ether extract are shown in the following table (Willey et al., 1952):

	1	2	3	4
Ether extract	2.84%	2.92%*	7.55%	7.54%*
Daily gain	2.22 lb	2.30 lb	2.22 lb	2.25 lb
Feed/CWT of gain	824 lb	822 lb	710 lb	733 lb

*Rations two and four were slightly higher in energy than one and three

A steer fattening ration was pelleted and fed with lot I receiving basal, lot II pellet containing 5.5% beef tallow, and lot III pellet containing 5.5% corn oil with the following results (Matsushima and Dowe, 1953):

	Lot I	Lot II	Lot III
Average daily gain	2.11 lb	2.00 lb	1.74 lb
Feed cost /CWT of gain	$27.67	$26.49	$31.96

Jones *et al.* (1942) fed a fattening ration to steers containing approximately 3% cottonseed oil and reported it to be a satisfactory source of energy. Other data reported have not been in agreement as to the effect of adding fat to the diet of ruminants. In most instances added fat has decreased digestibility of the ration, particularly cellulose. Feeding trials have failed to give conclusive information regarding either the utilization or economic feasibility of adding fat to a high energy-type ration.

EXPERIMENT I

Individual versus Group Feeding

Feed lot tests have consistently shown that varying degrees of individual variation can be expected of animals receiving similar treatment even though every precaution is taken in an effort to equalize groups. The primary purpose of this experiment was to determine whether data from individually-fed animals are more consistent and would thus allow smaller differences to be shown with lesser numbers than with data from group-fed animals.

Procedure

The physical design employed consisted of eight individual pens about 4' by 8' with four of the eight pens on each end of a larger enclosure which was approximately 15' by 18' and housed eight lambs, making eight group-penned and group-fed lambs versus eight individually-penned and individually-fed lambs. The pens were located in a brick barn, and at no time during the experiment did the lambs have access to the outside. All lambs were self-fed and had free access to water at all times. The basal ration consisted of: (in percent) cottonseed hulls, 35.0; ground yellow corn, 49.5; cottonseed meal, 12.4; di-calcium phosphate, 2.4; sodium chloride, 0.5; and vitamin A and D feeding oil, 0.2. In addition alfalfa ash and cane molasses ash were added to the ration at a rate to give consumption of about 10 gm of each per head per day. In both cases 10 gm was equivalent to about one-quarter lb of alfalfa hay and molasses respectively. The alfalfa ash was prepared by burning good quality alfalfa hay in an open barrel with further ashing in a muffle furnace at 600° F to remove remaining carbon. Molasses ash was prepared by heating dehydrated molasses in an open container over a gas burner and further ashing the remains in a muffle furnace at 600° F.

Sixteen western-type wether lambs were used in this experiment. The lambs were purchased at Del Rio, Texas, and immediately after being received at this station were sheared, drenched with a phenothiazine preparation for control of internal parasites, ear-tagged and paint-branded for easy identification. Following a ten-day recovery and orientation period the lambs were weighed, selected on a weight basis to include 16 lambs between the weights of 55 and 57 lb, and randomly allotted in the pens which were described previously.

Shrunk weights were obtained at the beginning and end of the experiment by removing feed and water from the animals 12 hours before weighing. Full weights were taken periodically throughout the experiment.

Due to continual dampness of the concrete floor of the pens during the first few days of the experiment, a sugar cane pulp litter was put down in all pens.

The experiment was terminated on the eighty-second day, and the lambs shipped to the Oklahoma City stockyards for slaughter. The carcass of each lamb was inspected on the killing floor for abnormalities and internal parasites. All lambs appeared normal with only minor parasitic infestation consisting of isolated cases of liver tapeworms. Warm and chilled weights were obtained on each carcass along with the federal grade.

Results and Discussion

Results of this experiment, which are shown in Appendix Table I, show that more uniform gains of somewhat lower magnitude were obtained when the lambs were individually-penned and individually-fed. Statistical analysis of the data (Snedecor, 1946) gives a standard deviation of 11.70 for the group-penned and group-fed lambs as compared to 2.72 for those individually-penned and individually-fed. Average daily gain and lb of feed required per lb of gain were 0.38 and 8.56, 0.33 and 9.54 for the group-fed and individually-fed animals respectively, with differences in weight gains being highly significant. It was observed during the experiment that the individually-penned and individually-fed lambs were rather nervous, while the group-penned and group-fed animals remained moderately quiet. It is possible that these observations, which suggest that the individually-penned and individually-fed animals were more active and restless, explain why these animals were less efficient in converting feed to gain in weight. Larger numbers of animals are needed before definite conclusions can be reached regarding daily gain, feed efficiency and behavior differences. Carcass grades were similar for the two treatments.

Summary and Conclusions

The experiment was designed to measure differences existing between lambs which are individually-penned and individually-fed versus group-penned and group-fed. On a fattening-type ration, using eight lambs per treatment, the individually-penned and individually-fed lambs gained significantly less (P less than .01) than those treated as a group, but they had a much smaller standard deviation (2.72 versus 11.70). Further work using larger numbers of animals is indicated.

EXPERIMENT II

The Effect of Mineral Additives on the Utilization of Semi-purified and Practical-Type Rations

Trial 1

Tefft (1954) found that significant increases in daily gains resulted when mineral combinations were added to a semi-purified ration containing cottonseed hulls as roughage. Further studies were indicated, and the following design was adopted for this purpose.

Procedure

Thirty-two western-type wether lambs were distributed on a weight basis into six groups. Following a 13-day standardization period during which time all lambs were receiving approximately two lb per head per day of a fattening-type ration, the lambs were re-allotted and started on the depletion phase. The diet during the depletion period for all groups was the basal ration shown as ration number one in Table I. The lambs were allowed to eat as much as they would clean up twice daily. Feeders were of individual stanchion type into which the sheep were fastened for approximately three hours per day with the time divided equally between morning and evening feedings. The animals were housed inside in box stalls which were approximately 10' square. During the time when lambs were not feeding, they had free access to the area within the stall and to fresh water. Individual feed records were kept.

Following the 28-day depletion phase the lambs were again re-allotted and divided into eight groups of four each, with individual weight averages within groups ranging from 57.8 to 62.0 lb. The repletion phase which lasted 35 days consisted of the following treatments fed in the same surroundings and in essentially the same way as the basal was fed during the depletion phase:

Ration No.	Treatment
1.	Basal
2.	Basal minus corn oil
3.	Basal plus synthetic alfalfa ash
4.	Basal plus synthetic alfalfa ash minus iron
5.	Basal plus synthetic alfalfa ash minus potassium
6.	Basal plus natural alfalfa ash
7.	Basal plus minor minerals of alfalfa ash
8.	Basal plus major minerals of alfalfa ash

Composition of the daily rations is shown in Table I. The synthetic alfalfa ash (Tillman <u>et al.,</u> 1954) was compounded from mineral salts to simulate the mineral composition of natural alfalfa ash. Composition of the synthetic alfalfa ash was as follows:

Material	gm	Material	gm
$KHCO_3$	960.00	$FeSO_4.7\ H_2O$	500.00
K_2HPO_4	348.00	$NaB_4O_7.10\ H_2O$	5.70
$CaCl_2$	277.00	$MnSO_4.H_2O$	3.00
$Ca(OH)_2$	348.00	$CuSO_4.5\ H_2O$	5.00
$MgSO_4.7\ H_2O$	592.00	ZnO	1.06
$NaHCO_3$	319.00	$CoCl_2.6\ H_2O$	0.007
		MoO_3	0.003

Natural alfalfa ash was obtained by the methods described in Experiment I. The minor mineral mix consisted of the minor minerals listed in the right column and in the proportions shown in the composition of synthetic alfalfa ash. The major mineral mix consisted of the major minerals listed in the left column and in the proportions shown in the composition of synthetic alfalfa ash.

Following five weeks on the repletion phase all groups except the basal and the basal plus minor minerals were taken off trial. For further comparisons these two groups were carried an additional two weeks with both groups receiving the basal plus synthetic alfalfa ash. Shrunk weights as described in Experiment I were taken at the beginning and end of both the depletion and repletion phases with full weights taken periodically throughout the trial.

Results and Discussion

During the depletion phase the lambs exhibited abnormal behavior in that they appeared to be hungry but refused to eat appreciable amounts of the basal ration; however, weight losses during the depletion period were slightly less than those reported during depletion phases by Tefft (1954). From time to time throughout the trial lambs were observed trying to pull paper labels off the stanchions and chewing on the metal latches used on the stanchions. The wool on some of the lambs appeared to become detached from the skin rather easily, and wool-pulling by lambs was common. Statistical analysis of variance of weight losses during the depletion phase revealed no significant differences in groups.

In the repletion phase of the trial it became evident after the first week that the lot on minor minerals was losing weight much more rapidly than any other group. On the twentieth day the trace mineral group began sorting the cottonseed hulls from the basal and refusing to eat the basal portion of the ration. From that point on, it was necessary to weigh back feed refusals periodically from the lot receiving the minor mineral additive, depending upon individual consumption within the lot. Individual performance records for this trial are shown in Appendix Table II.

Total lot gains for the repletion period were as follows:

Ration No.	Treatment	Total lot Gain (lb)
1.	Basal	-19.5
2.	Basal minus corn oil	- 8.5
3.	Basal plus synthetic alfalfa ash	-12.5
4.	Basal plus synthetic alfalfa ash minus iron	-10.5
5.	Basal plus synthetic alfalfa ash minus potassium	-10.0
6.	Basal plus natural alfalfa ash	- 6.0
7.	Basal plus minor minerals of alfalfa ash	-38.0
8.	Basal plus major minerals of alfalfa ash	9.5

The two groups which were carried an additional two weeks on a ration of the basal plus synthetic alfalfa ash showed no significant differences in weight gains during the additional period.

When data from the eight treatments were subjected to analysis of variance, differences were highly significant. The multiple range test (Duncan, 1955) indicated that ration eight gave significantly higher gains (P less than .01) than rations seven and one. Ration seven had significantly lower gains (P less than .01) than all rations except number one.

Summary and Conclusions

A depletion-repletion type regimen was used with 32 lambs to test the effect of various mineral combinations found in alfalfa ash on a semi-purified ration containing cottonseed hulls as roughage.

The addition of major minerals of alfalfa ash to the basal ration gave highly significant increases in gains over the basal or basal plus minor minerals of alfalfa ash. Sheep receiving the basal plus minor minerals of alfalfa ash had gains that were significantly lower than those for all treatments except the basal ration. The minor minerals of alfalfa ash when mixed with the basal ration gave some indications of being unpalatable.

TABLE I

RATIONS USED IN SEMI-PURIFIED DIET OF EXPERIMENT II, TRIAL ONE

Feed	Ration 1	2	3	4	5	6	7	8
	%	%	%	%	%	%	%	%
Cottonseed Hulls	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00
Cerelose	35.70	37.60	35.70	35.70	35.70	35.70	35.70	35.70
Corn Oil	2.40		2.40	2.40	2.40	2.40	2.40	2.40
Urea	2.00	2.11	2.00	2.00	2.00	2.00	2.00	2.00
Di-calcium Phosphate	2.00	2.11	2.00	2.00	2.00	2.00	2.00	2.00
Gelatin	1.60	1.69	1.60	1.60	1.60	1.60	1.60	1.60
Sodium Chloride	.40	.42	.40	.40	.40	.40	.40	.40
Sodium Sulfate	.32	.34	.32	.32	.32	.32	.32	.32
Mono-Sodium Phosphate	.50	.53	.50	.50	.50	.50	.50	.50
Vitamin A and D Feeding Oil	.08	.08	.08	.08	.08	.08	.08	.08
Synthetic Alfalfa Ash (gm)			49.00					
Synthetic Alfalfa Ash minus Iron (gm)				43.00				
Synthetic Alfalfa Ash minus Potassium (gm)					46.00			
Natural Alfalfa Ash (gm)						28.00		
Minor Minerals of Alfalfa Ash (gm)							6.00	
Major Minerals of Alfalfa Ash (gm)								43.00

Trial 2

Results of trial 1 indicate that wide differences in gains on semi-purified rations due to certain added mineral combinations may be expected. Tefft (1954) reported a 47% increase in feed utilization by lambs on a fattening-type ration when alfalfa ash was added to the ration. To further test the effects of mineral combinations such as were used in trial 1, a basal fattening ration was used.

Procedure

The following treatments were used:

Basal
Basal plus minor minerals of alfalfa ash (.125 lb/CWT of ration)
Basal plus major minerals of alfalfa ash (.95 lb/CWT of ration)
Basal plus synthetic alfalfa ash (1.0 lb/CWT of ration)

The minor and major mineral mixes as well as the synthetic alfalfa ash were the same as those used in trial 1. Vitamins A and D were supplied by 0.05% of "Quadrex" (micratized A and D supplement).

Twenty-eight western-type wethers ranging in weight between 57 and 71 lb were sheared and drenched ten days prior to the start of the experiment. The lambs were allotted on a weight basis with average starting weight being 65.7 lb. Groups and treatments were randomly assigned to pens. The pens consisted of box stalls approximately 12' by 12' which were open to small outside fenced enclosures with lambs being allowed access to either area. All groups were self-fed and given free access to water throughout the trial. A shrunk weight as described in Experiment I was obtained at the start and finish with full weights taken periodically throughout the trial.

After 97 days the trial was terminated, and the lambs were marketed as described in Experiment I with individual carcass inspection being made along with a record of carcass weight and federal grade. No abnormalities were noted, and lambs appeared to be free of internal parasites.

Results and Discussion

Weight, feed intake and feed efficiency records are shown in Appendix Table III. The ration basal plus trace minerals appeared at times to be less palatable than the other three rations, with the lambs tending to push aside the feed in the trough in preference for fresh feed coming down through the feeder. All lambs made excellent gains. The daily gains and feed efficiency averages in increasing order of gain were as follows:

Ration	Daily Gain	Feed Efficiency
Basal plus minor minerals of alfalfa ash	0.40	8.95
Basal	0.41	9.44
Basal plus major minerals of alfalfa ash	0.46	8.28
Basal plus synthetic alfalfa ash	0.48	8.42

Since all lots were group-fed, statistical analysis of differences in feed efficiency was not possible; however, there is some indication that the basal ration was deficient in minerals since the lowest feed efficiency was on the basal ration. Analysis of variance of the weight gains revealed no significant differences between rations.

Similarity was noted in trials 1 and 2 with the basal plus minor minerals being the poorest-gaining lot in both cases; however, the difference was not significant in trial 2. It seemed apparent in trial 1 that minor minerals adversely affected palatability of the ration with somewhat the same effect but to a lesser degree being noted in trial 2. The effect upon palatability may partially explain why the trace mineral lots in both trials were the poorest gainers. In the semi-purified ration major minerals gave significantly higher gains than did synthetic alfalfa ash; however, in trial 2 there appeared to be no difference between the rations.

Summary and Conclusions

Twenty-eight lambs in a 97-day group-feeding trial were used to evaluate the addition of synthetic alfalfa ash, the minor and major elements of synthetic alfalfa ash to a fattening-type ration containing cottonseed hulls as the only roughage. The addition of synthetic alfalfa ash or its major elements seemed to improve daily gains and feed efficiencies. Statistical analysis of weight gains revealed no significant differences due to treatment.

EXPERIMENT III

The Effect of Fat upon Low Quality Roughage Utilization

Part A - Growth

Trial 1

Use of the basal ration as described in Experiment II resulted in consistent losses of weight during both the depletion and repletion phases of the experiment. The ration used in this trial was designed to resemble the ration previously mentioned with certain modifications in an attempt to find a semi-purified basal which would promote gains in the experimental animals.

Procedure

The basal ration used in this experiment consisted of the following ingredients per head per day: (in gm) cerelose, 100; Dracket (soybean protein), 100; di-calcium phosphate, 7.7; "Quadrex" (micratized vitamin A and D supplement), 0.46; and cottonseed hulls, ad libitum.

Treatments consisted of:

Basal
Basal plus 24 gm corn oil
Basal plus 28 gm alfalfa ash
Basal plus 28 gm alfalfa ash plus 24 gm corn oil

Twenty-four western- and native-type lambs were allotted on a weight basis into eight nearly equal groups. Groups were placed in stalls similar to those described in Experiment II. A replicate of each ration was obtained by dividing the eight pens into two blocks of four each and assigning at random each of the four treatments to a lot within each block.

All groups were self-fed the concentrates previously mentioned which were mixed with the approximate amount of cottonseed hulls each group would consume daily. Corn oil and alfalfa ash were mixed into the designated rations at time of feeding. Throughout the trial all lambs had free access to water and the area within the stall. Shrunk weights as described in Experiment I were taken at the beginning and end with periodic weights taken throughout the 62-day trial.

Results and Discussion

Individual limits of loss and gain for the 62-day trial ranged from a minus 3.5 to a plus 31.0 lb with data presented in Appendix Table IV. Analysis of variance of the weight gains failed to show a significant difference between treatments. Differences in feed efficiency were significant with the basal plus corn oil being less efficient; however, the addition of corn oil to the ration appeared to have a beneficial effect upon palatability.

The following table lists the rations in order of decreasing efficiency:

	Feed Efficiency	Daily Hull Intake	Daily Gain
Basal plus alfalfa ash	7.47	1.48	0.26
Basal plus alfalfa ash plus corn oil	7.77	1.63	0.27
Basal	8.25	1.50	0.24
Basal plus corn oil	10.46	1.63	0.20

Although the basal plus alfalfa ash-fed group had the highest feed efficiency, the lot receiving basal plus alfalfa ash plus corn oil had slightly higher daily gains.

Summary and Conclusions

Twenty-four lambs allotted on a weight basis were group-fed a semi-purified ration containing cottonseed hulls as roughage. Weight gains were subjected to statistical analysis but failed to show significant differences between treatments; however, analysis of variance of feed efficiencies did show significant differences. The multiple range test showed that the basal plus corn oil group was significantly less efficient than those receiving any of the other three rations.

Trial 2

Widely varied results have been reported as a result of adding fats to ruminant rations. Brooks et al. (1954) found that the addition of 64 gm of corn oil to the ration of sheep significantly decreased crude fiber digestibility.

Procedure

The following trial was designed to test the effects of corn oil in a lamb fattening ration. Composition of the basal ration was as follows: (in percent) cottonseed hulls, 35; ground yellow corn, 50.5; cottonseed meal, 12.4; sodium chloride, 0.5; di-calcium phosphate, 1.0; limestone, 0.5; and "Quadrex" (micratized vitamin A and D supplement), 0.1.

Treatments consisted of:

Basal
Basal plus 10% corn oil
Basal plus 10% corn oil plus 8.5% alfalfa meal
Basal plus 10% corn oil plus 0.85 lb alfalfa ash/CWT of ration

Additives to the basal ration replaced corn and cottonseed meal so as to keep constant (as nearly as possible) the crude protein content of all rations. Calcium and phosphorus levels were also maintained constant by varying the di-calcium and limestone portions of the ration. The alfalfa meal was from poor quality hay as was the alfalfa ash which was prepared as described in Experiment I.

Sixteen western-type wether lambs were allotted on a weight basis into four groups with lots averaging from 68.8 to 70.9 lb per animal.

Treatments were assigned to lots at random.

All lots were housed indoors in stalls approximately 8' by 10'. Rations were self-fed and the animals given free access to water throughout the trial. This trial was conducted during weather in which temperatures frequently rose above 90° F. Due to the temperature and high content of corn oil, it was necessary to mix the rations weekly. No rancidity or offensive odors were noted. Shrunk weights as described in Experiment I were taken at the beginning and end of the 36-day trial with full weights taken periodically throughout the trial.

Results and Discussion

It was apparent from the start of the experiment that the lambs on the three rations containing corn oil found their diets less palatable than the basal ration. This is not in agreement with trial 1; however, the percent of corn oil in trial 2 was much higher.

All lots on the corn oil rations formed soft, straw-colored pellets throughout the trial; however, no scouring was noted. Similar trends in daily gain and feed efficiency were shown as can be seen in Appendix Table V, with the addition of corn oil to the basal ration giving a reduction in both cases.

The rations are listed below in order of decreasing daily gain and feed efficiency:

	Daily Gain	Feed Efficiency
Basal	0.36	8.17
Basal plus corn oil plus alfalfa meal	0.24	10.46
Basal plus corn oil plus alfalfa ash	0.21	12.19
Basal plus corn oil	0.18	12.28

There was a noticeable difference in daily gains; however, individual variation was large and numbers limited with no significant difference between treatments.

Summary and Conclusions

Sixteen lambs were divided into four groups and group-fed a fattening-type ration with additions of 10% corn oil and/or alfalfa ash or alfalfa meal. Analysis of the data failed to show any treatment differences in weight gains. It seems that definite trends were established in regard to feed efficiency. The basal minus corn oil group was more efficient in both trials 1 and 2 than the basal plus corn oil.

Part B - Digestibility

Trial 1

Brooks *et al.* (1954) reported that corn oil added to a basal ration of cottonseed hulls and casein significantly lowered both cellulose and protein digestibility in sheep. Depressing effects noted were partially overcome by the addition of alfalfa ash. The purpose of this trial was to study further the effect of fat and alfalfa ash upon the utilization of cottonseed hulls.

Procedure
Period 1

A factorial design was employed in this experiment to test the digestibility of the basal ration used in Experiment II, trial 1. Composition and daily allowance of the ration are shown in Table II.

Treatments consisted of:

Basal
Basal plus 2.4% corn oil
Basal plus 28 gm alfalfa ash
Basal plus 2.4% corn oil plus 28 gm alfalfa ash

Alfalfa ash was prepared as described in Experiment I.

Sixteen western-type wether lambs averaging 73.7 lb each were allotted on a weight basis into four nearly equal groups. Each group was placed in a stall previously described in Experiment II, trial 1. Treatments were assigned to the stalls at random.

Alfalfa ash was mixed into the designated rations at time of feeding. All lambs were individually-fed twice daily in stanchion-type feeders. The lambs had free access to water while not locked in the stanchions. Feedings were about nine hours apart with lambs allowed to eat until either the allowance was cleaned up or approximately one and one-half hours had elapsed.

Following a 10-day preliminary period, complete collection was made using a harness and bag as described by Tillman et al. (1954). Collection was made once daily, and feces were dried in a forced draft oven at 70° C. The total 10-day collections of feces were stored in open metal containers and after allowing five days for equilibrium with the air were sampled for chemical analysis.

Period 2

In order to increase the number of lambs per treatment, the trial was replicated using three western-type wether lambs per treatment. Other details were as previously described. Analysis of feed and feces for both periods was made according to accepted methods (A. O. A. C., 1950).

Results and Discussion

During the first three days of the collection period of period 1, two lambs receiving the basal plus alfalfa ash ration began to scour badly, and collections were discontinued. After a four-day lapse feces again became normal, and a full 10-day collection period was obtained for both lambs. As seen in Appendix Table VI, no trend was apparent during the initial period of this trial with digestion coefficients showing rather large variations and some overlapping. Coefficients for period 2, also rather variable, are shown in Appendix Table VII. Negative digestive coefficients on rations which did not contain corn oil were probably due to a very low ether extract content of the rations along with the normal output of metabolic fat appearing in the feces.

Analysis of variance was applied to the data from period 1 with crude fiber being the only ration component which differed significantly due to treatment. The average apparent digestion coefficients for crude fiber were: basal, 49.1; basal plus corn oil, 54.3; basal plus alfalfa ash, 43.8; and basal plus corn oil plus alfalfa ash, 56.0. The multiple range test shows that the basal plus alfalfa ash had significantly lower digestibility coefficients than any of the other three rations.

Analysis of variance of data obtained in period 2 shows significant differences for dry matter, crude protein and organic matter digestibility coefficients. In each case the digestion coefficients when subjected to the multiple range tests showed the basal plus corn oil plus alfalfa ash to have significantly lower values than any of the other three rations.

When data from the two trials were combined for analysis, there was a significant difference in NFE digestion coefficients, with the basal plus corn oil being significantly lower (P less than .05) than the other rations while the basal plus alfalfa ash was significantly higher than all other rations. There was no difference between the basal and the basal plus corn oil plus alfalfa ash in the case of dry matter, crude fiber and organic matter. The trial-by-treatment interaction was highly significant.

Summary and Conclusions

A two by two factorial design involving seven lambs per treatment was used to study the effect of corn oil and/or alfalfa ash upon the digestibility of a semi-purified diet which contained cottonseed hulls as the only roughage. The addition of corn oil significantly decreased the digestibility of NFE while the addition of alfalfa ash gave significant increases. Trial-by-treatment interaction was significant in the case of dry matter, crude fiber and organic matter.

TABLE II

RATIONS USED IN THE OKLAHOMA A. AND M. BASAL DIGESTION TRIALS

Feed	Ration 1	2	3	4
	%	%	%	%
Cottonseed Hulls	55.00	55.00	55.00	55.00
Cerelose	37.60	35.70	37.60	35.70
Corn Oil		2.40		2.40
Urea	2.11	2.00	2.11	2.00
Di-calcium phosphate	2.11	2.00	2.11	2.00
Gelatin	1.69	1.60	1.69	1.60
Sodium Chloride	.42	.40	.42	.40
Sodium Sulfate	.34	.32	.34	.32
Mono-sodium Phosphate	.53	.50	.53	.50
Vitamin A and D Feeding Oil	.08	.08	.08	.08
Alfalfa Ash (gm)			28.00	28.00

Daily allowance consisted of 274 gm of cottonseed hulls and 224 gm of the concentrate mixture. Alfalfa ash was added to the rations indicated.

TABLE III

COMPOSITION OF FEEDS USED IN THE OKLAHOMA A. AND M. BASAL DIGESTION TRIALS

Period 1

Feed	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Ash
	%	%	%	%	%	%
Cottonseed Hulls	91.0	3.9	0.7	40.9	42.8	2.8
Concentrate with Corn Oil	94.8	15.8	5.3		66.5	7.1
Concentrate minus Corn Oil	94.0	17.3			70.2	6.4
Period 2						
Cottonseed Hulls	90.6	2.8	0.3	31.0	54.1	2.4
Concentrate with Corn Oil	75.5	15.2	5.3		48.4	6.6
Concentrate minus Corn Oil	77.7	14.3			56.9	6.7

TABLE IV

AVERAGE DIGESTIBILITY COEFFICIENTS OF THE OKLAHOMA A. AND M. BASAL RATION

Periods 1 and 2

Ration	No. of Animals	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	7	63.2	47.3	-23.6	48.2	75.2	65.7
Basal plus Corn Oil	7	65.8	49.6	90.3	52.8	73.4	66.9
Basal plus Alfalfa Ash	7	63.9	46.0	- 6.2	48.0	78.0	67.4
Basal plus Corn Oil plus Alfalfa Ash	6	65.1	46.1	92.8	47.3	74.8	66.5

Trial 2

To further test the effect of corn oil and/or alfalfa ash upon the digestibility of a ration containing cottonseed hulls as roughage a ration similar to that used by Brooks et al. (1954) was adopted and used in a two by two factorial design.

Procedure
Period 1

Sixteen western-type wether lambs weighing approximately 73.7 lb each were allotted on a weight basis into four nearly equal groups. Each group was placed in a stall as described in Experiment II, trial 1. Treatments were assigned at random to the stalls. Composition of the ration can be seen in Table V. Daily allowance during period 1 consisted of 913 gm of the basal ration plus additives as indicated.

Treatments consisted of:

Basal
Basal plus 32 gm corn oil
Basal plus 28 gm alfalfa ash
Basal plus 32 gm corn oil plus 28 gm alfalfa ash

Corn oil and alfalfa ash were mixed into the designated rations at time of feeding. Method of feeding, facilities used, preliminary and collection periods were essentially the same as described in trial 1. Analysis of feed and feces was made according to accepted methods (A. O. A. C., 1950).

Period 2

Twelve western-type wether lambs of approximately the same weight as those used in period 1 of this trial were allotted into four nearly equal lots and assigned to stalls previously described in Experiment II, trial 1. Treatments were assigned at random to the stalls. It was necessary to reduce the daily intake as shown in period 1 to 713 gm.

Composition of the ration fed in period 2 can be seen in Table V. The preliminary period, collection and analysis are essentially the same as described previously in period 1.

Results and Discussion

Consumption of the daily allowance was consistent in period 1 of the trial with feed refusal for only one lamb on the basal ration. The feed refusal was weighed back, analyzed and corrections made accordingly in the digestion coefficients. The lambs in period 2 refused to eat the amount consumed by the sheep in period 1. This may have been due to hot, humid weather during the second period. Since the daily consumption differed for the two periods, it was necessary to treat them as separate trials for statistical analysis. Individual apparent digestion coefficients are shown in Appendix Tables VIII and IX.

Analysis of variance of data obtained in the first period of this trial showed significant differences in the digestibility of crude fiber and ether extract. Differences in crude fiber digestibility as shown by the multiple range test are as follows: the basal plus corn oil was significantly lower than the basal plus corn oil plus ash and the basal minus corn oil. Differences shown in ether extract digestion coefficients were due to the addition of highly digestible corn oil to two of the rations.

When data of period 2 were subjected to analysis of variance, the digestibilities of dry matter and organic matter were significantly different, and in the case of NFE the differences were highly significant. The multiple range test showed that in the case of dry matter, NFE and organic matter, the basal group had significantly lower digestibilities than those receiving the other rations. The group receiving corn oil as the only additive had significantly lower digestibilities of dry matter, NFE and organic matter than when alfalfa ash was an additive.

Some variation in digestion coefficients was noted throughout both periods of the trial. The first period is in partial agreement with Brooks et al. (1954) in showing a rather consistent, but not significant except in the case of crude fiber, lowering of digestion coefficients in the ration basal plus corn oil. Period 2 differs in that the basal group gave unusually variable coefficients with one of the three lambs from this group removed from the trial due to feed refusal. Since all rations except the basal gave fairly uniform coefficients, which showed the previously noted trend, it seems highly probable that the basal group due to unknown causes did not give true results.

Summary and Conclusions

A digestion trial divided into two periods was conducted using a semi-purified ration with cottonseed hulls as the only roughage. In the first period 913 gm of the basal ration was fed with four lambs per treatment. In the second period the same basal ration was used but the daily allowance was 713 gm with three lambs per treatment. Due to daily intake differences between the periods, it was necessary to consider them as separate trials for statistical analysis.

In period 1 the basal plus corn oil ration gave slightly lower digestion coefficients than did the other rations; however, only in the case of crude fiber was the difference significant (P less than .05).

In the second period basal minus corn oil showed consistently lower digestion coefficients than the other three rations, with basal plus corn oil also lower than the two rations containing alfalfa ash except in the case of crude fiber where basal plus corn oil had slightly higher coefficients than any other ration. In the second period significant differences were shown in dry matter and organic matter digestion coefficients and highly significant differences for NFE coefficients.

TABLE V

RATIONS USED IN THE MISSOURI BASAL DIGESTION TRIALS

Feed	Ration 1	2	3	4
	%	%	%	%
Cottonseed Hulls	87.6	87.6	87.6	87.6
Casein	10.3	10.3	10.3	10.3
Mineral Mix*	2.0	2.0	2.0	2.0
Vitamin A and D Feeding Oil	0.1	0.1	0.1	0.1
Corn Oil (gm)		32.0		32.0
Alfalfa Ash (gm)			28.0	28.0

*Mineral mix was made up of equal parts sodium chloride and di-calcium phosphate

TABLE VI

COMPOSITION OF FEEDS USED IN THE MISSOURI BASAL DIGESTION TRIALS

Period 1

Feed	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Ash
	%	%	%	%	%	%
Cottonseed Hulls	90.7	3.9	0.7	40.9	42.8	2.8
Casein	92.3	82.3	1.7		2.1	6.3
Corn Oil	100.0		100.0			

Period 2

Feed	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Ash
Cottonseed Hulls	90.6	2.8	0.3	31.0	54.1	2.4
Casein	90.7	85.9	0.9		3.2	0.7
Corn Oil	100.0		100.0			

TABLE VII

AVERAGE DIGESTIBILITY COEFFICIENTS OF THE
MISSOURI BASAL RATION

Period 1

Ration	No. of Animals	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	4	54.0	56.3	73.8	58.5	50.3	54.2
Basal plus Corn Oil	4	50.1	57.7	86.4	50.9	52.1	51.9
Basal plus Alfalfa Ash	4	53.6	60.4	76.1	53.8	59.5	54.1
Basal plus Corn Oil plus Alfalfa Ash	4	54.9	60.4	92.9	56.2	58.7	56.3

TABLE VIII

AVERAGE DIGESTIBILITY COEFFICIENTS OF THE
MISSOURI BASAL RATION

Period 2

Ration	No. of Animals	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	2	47.7	68.1	-16.6	37.7	46.8	47.7
Basal plus Corn Oil	3	57.3	73.9	80.0	53.0	51.3	57.8
Basal plus Alfalfa Ash	3	60.6	76.8	-50.0	47.7	63.0	60.9
Basal plus Corn Oil plus Alfalfa Ash	3	61.8	76.4	80.0	48.9	62.1	62.0

Trial 3

In view of the effects exhibited by corn oil in previously mentioned growth trials, it was decided to test the digestibility of a ration containing ground corncobs as roughage, using treatments similar to those of trials 1 and 2.

Procedure
Period 1

Treatments consisted of:

Basal
Basal plus 21 gm corn oil
Basal plus 28 gm alfalfa ash
Basal plus 21 gm corn oil plus 28 gm alfalfa ash

Alfalfa ash was obtained as described in Experiment I. Dehydrated ground corncobs were supplied from a commercial firm located in the Kansas City, Missouri, area.

Twelve lambs of native-western crossbreeding weighing between 51 and 70 lb were purchased for use in this trial. The lambs were sheared and drenched with a phenothiazine preparation 10 days before the start of the trial. The lambs were allotted on a weight basis into four nearly equal lots. The lots were randomly assigned to stalls which were previously described in Experiment II, trial 1.

Composition and daily allowance of the ration is shown in Table IX. Corn oil and alfalfa ash were mixed into the designated rations at time of feeding. Lambs were fed twice daily in individual stanchions and were allowed the freedom of the area within the stall and free access to water except when eating.

Following a 10-day preliminary period a total collection of feces was made for a 10-day period with storage and sampling of the feces conducted as described in trial 1.

After completion of the collection period the lambs were put on a standardization ration for one week. The composition of this ration was as follows: (in percent) ground corncobs, 16.7; ground yellow corn, 33.3; corn gluten meal, 8.3; and alfalfa hay, 41.7.

Period 2

Following the standardization period the lambs were randomly allotted on a weight basis into four groups and a replication obtained for each of the four treatments.

Analysis of feed and feces was made according to accepted methods (A. O. A. C., 1950).

Results and Discussion

During period 1, one lamb from the basal plus alfalfa ash had a small feed refusal which was weighed back, analyzed and corrections made in the digestion coefficients. One lamb from the basal plus corn oil lot refused to eat during period 2 and was removed from the trial.

Somewhat more uniform digestion coefficients were obtained in period 1 than during period 2; however, both periods showed significant differences between rations. Both dry matter and organic matter digestion coefficients were higher for period 1 than period 2, giving a highly significant interaction. Hot, humid weather during the time the replication was conducted may have caused lowered digestibilities. Digestion coefficients are shown in Appendix Tables X and XI. Average digestion coefficients for period 1 of the ground corncob trial are as follows:

	Dry Matter	Organic Matter
Basal	73.6	75.4
Basal plus 21 gm corn oil	66.8	68.6
Basal plus 28 gm alfalfa ash	73.9	76.9
Basal plus 21 gm corn oil plus 28 gm alfalfa ash	73.5	76.5

Average digestion coefficients for the basal plus corn oil are notably lower than for the other rations. This difference was shown to be highly significant when subjected to analysis of variance. The multiple range test shows the highly significant difference to lie between basal plus corn oil and the three remaining rations.

Average digestion coefficients for the replication are as follows:

	Dry Matter	Organic Matter
Basal	67.8	69.7
Basal plus 21 gm corn oil	61.6	62.9
Basal plus 28 gm alfalfa ash	72.1	77.5
Basal plus 21 gm corn oil plus 28 gm alfalfa ash	71.4	76.4

The same trend toward lowered digestibility of basal plus corn oil was apparent in period 2. When subjected to analysis of variance, organic matter digestibility differed in a highly significant manner. The digestibility of dry matter also approached this level. The multiple range test applied to dry matter digestion coefficients showed basal plus corn oil to be significantly different than all other rations. A highly significant difference for organic matter digestibility was shown between basal plus corn oil and basal plus alfalfa ash as well as basal plus corn oil plus alfalfa ash. Difference in digestibility of organic matter between basal and basal plus corn oil was not significant.

Data from periods 1 and 2 were combined with the average digestion coefficients as follows:

	Dry Matter	Organic Matter
Basal	70.7	72.5
Basal plus 21 gm corn oil	64.7	66.3
Basal plus 28 gm alfalfa ash	72.5	76.5
Basal plus 21 gm corn oil plus 28 gm alfalfa ash	73.0	77.2

Statistical analysis of the combined data shows highly significant differences in both dry matter and organic matter digestibility. The multiple range test shows that in both cases basal plus corn oil differs in a highly significant manner from the other three rations. Significant trial and trial-by-treatment interaction is also shown. Trial differences as previously mentioned may have been due to hot, humid weather during the replication.

Summary and Conclusions

In a two by two factorial design involving 230 sheep days, it was found that corn oil added to a ration containing ground corncobs as the only roughage significantly reduced the digestibility of dry and organic matter. The addition of alfalfa ash had very little effect upon the digestibility of the basal ration but significantly improved the digestibility of the ration containing corn oil.

TABLE IX

RATIONS USED IN THE GROUND CORNCOB DIGESTION TRIALS

Feed	Ration 1	2	3	4
	%	%	%	%
Ground Corncobs	45.6	45.6	45.6	45.6
Ground Yellow Corn	25.3	25.3	25.3	25.3
Corn Gluten Meal	20.3	20.3	20.3	20.3
Corn Syrup	7.1	7.1	7.1	7.1
Di-calcium Phosphate	1.0	1.0	1.0	1.0
Sodium Chloride	.7	.7	.7	.7
Cobalt Sulfate (mgm)	1.2	1.2	1.2	1.2
"Quadrex" (A and D supplement) (gm)	2.0	2.0	2.0	2.0
Corn Oil (gm)		21.0		21.0
Alfalfa Ash (gm)			28.0	28.0

Daily ration consisted of 700 gm in proportions as indicated above plus cobalt sulfate and "Quadrex" in amounts indicated. Corn oil and alfalfa ash were added to designated rations.

TABLE X

COMPOSITION OF FEEDS USED IN THE GROUND CORNCOB DIGESTION TRIALS

Period 1

Feed	Dry Matter	Organic Matter	Ash
	%	%	%
Ground Yellow Corn	88.7	87.4	1.3
Corn Gluten Meal	91.9	88.7	3.2
Ground Corncobs	92.6	90.2	2.7
Corn Oil		100.0	
Corn Syrup	81.6		0.3
	Period 2		
Ground Yellow Corn	87.9	86.5	1.4
Corn Gluten Meal	91.7	88.5	3.2
Ground Corncobs	93.8	88.0	5.8
Corn Oil		100.0	
Corn Syrup	81.6		0.3

TABLE XI

AVERAGE DIGESTIBILITY COEFFICIENTS OF THE GROUND CORNCOB BASAL RATION

Periods 1 and 2

Ration	No. of Animals	Dry Matter	Organic Matter
Basal	6	70.7	72.5
Basal plus Corn Oil	5	64.7	66.3
Basal plus Alfalfa Ash	6	72.5	76.5
Basal plus Corn Oil plus Alfalfa Ash	6	73.0	77.2

LITERATURE CITED

Allen, N. N. 1934. The fat percentage of milk as affected by feeding fats to dairy cows. J. Dairy Sci. 17:379.

Allison, H. O. 1917. Preparation of corn for fattening two year old steers. Mo. Agr. Exp. Sta. Bul. 149.

Becker, D. E. and S. E. Smith. 1949. The metabolism of cobalt in lambs. J. Animal Sci. 8:615.

Beeson, W. M. and T. W. Perry. 1952. Balancing the nutritional deficiencies of roughages for beef steers. J. Animal Sci. 11:501.

Bell, D. S. 1949. Corncobs for lambs. Ohio Agr. Exp. Sta. Res. Bul. 690.

Bennett, L. 1955. Alfalfa hay and dehydrated alfalfa meal in fattening rations for steer calves. Master's Thesis. Okla. Agr. and Mech. Col.

Bentley, O. G. and E. W. Klosterman. 1953. Quality of roughage may be key to need for trace minerals. Ohio Agr. Exp. Farm and Home Res. Bul. 280.

Bentley, O. G. and A. L. Moxon. 1952. A semi-synthetic ration for studying the trace element requirements of cattle. J. Animal Sci. 11:756.

Bentley, O. G., S. Vanecho, C. H. Hunt and A. L. Moxon. 1953. Nutritional requirements of rumen microorganisms for cellulose digestion in vitro. J. Animal Sci. 12:908.

Brooks, C. C., G. B. Garner, C. W. Gehrke, M. E. Muhrer and W. H. Pfander. 1954. The effect of added fat on the digestion of cellulose and protein by ovine rumen microorganisms. J. Animal Sci. 13:758.

Bryant, M. P. and L. A. Burkey. 1953. Numbers and some predominant groups of bacteria in the rumen of cows fed different rations. J. Dairy Sci. 36:218.

Burroughs, W., N. A. Frank, P. Gerlaugh and R. M. Bethke. 1950 a. Preliminary observations upon factors influencing cellulose digestion by rumen microorganisms. J. Nutr. 40:9.

Burroughs, W., P. Gerlaugh and R. M. Bethke. 1948. Influence of alfalfa ash and water extract of alfalfa upon roughage digestion in cattle. J. Animal Sci. 7:522.

Burroughs, W., P. Gerlaugh and R. M. Bethke. 1949. The use of an artificial rumen in studying roughage digestion with rumen microorganisms under controlled laboratory conditions. J. Animal Sci. 8:616.

Burroughs, W., P. Gerlaugh and R. M. Bethke. 1950 b. The influence of alfalfa hay and fractions of alfalfa hay upon the digestion of ground corncobs. J. Animal Sci. 9:207.

Burroughs, W., P. Gerlaugh, A. F. Schalk, E. A. Silver and L. E. Kunkle. 1945. The nutritive value of corncobs in beef cattle rations. J. Animal Sci. 4:373.

Burroughs, W., A. Latona, P. DePaul, P. Gerlaugh and R. M. Bethke. 1951. Mineral influences upon urea utilization and cellulose digestion by rumen microorganisms using the artificial rumen technique. J. Animal Sci. 10:693.

Byers, J. H., I. R. Jones and J. R. Haag. 1949. The comparative value of high and low fat concentrates with alfalfa hay. J. Dairy Sci. 32:596.

Chappel, C. F., R. J. Sirny, C. K. Whitehair and R. MacVicar. 1952. Effect of mineral supplements on digestibility of a corncob ration by sheep. J. Animal Sci. 14:153.

Corrie, F. E. 1951. Feeding farm animals, 50. Feeding stuffs as sources of minerals. Fertiliser, Feeding Stuffs and Farm Supplies Journal 37:717.

Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:383.

Duncan, D. B. 1955. Multiple range and multiple F tests. J. Biometrics II (1):1.

Emery, F. E., J. R. Chamberlain and B. W. Kilgore. 1891. Feeding cottonseed hulls and meal for production of beef. N. C. Agr. Exp. Sta. Bul. 81.

Emery, F. E. and B. W. Kilgore. 1891. I. The digestibility of cottonseed hulls; II. The digestibility of a ration of cottonseed hulls and cottonseed meal; and III. Comparison of composition and digestibility of wheat straw and cottonseed hulls. N. C. Agr. Exp. Sta. Bul. 80c.

Emery, F. E. and B. W. Kilgore. 1892. Digestion experiments with pulled fodder, crimson clover hay, cowpea-vine hay, corn silage, soja bean silage, and cottonseed-raw, roasted, hulls and meal. N. C. Agr. Exp. Sta. Bul. 87d.

Emery, F. E. and B. W. Kilgore. 1894. Digestion experiments with soybean hay, cat-tail millet, Johnson grass hay, sorghum fodder and bagasse, peanut-vine hay, cottonseed meal, cottonseed hulls, crimson clover hay, corn meal, corn-and-cob meal, and corn silage. N. C. Agr. Exp. Sta. Bul. 97.

Ewell, R. H. 1953. The outlook for inedible fats and oils. J. Agr. and Food Chem. 1:552.

Forbes, E. B., R. W. Swift, J. W. Bratzler, A. Black, E. J. Thacker, C. E. French, L. F. Marcy, R. F. Elliott and H. P. Moore. 1943. Conditions affecting the digestibility and metabolizable energy of feeds for cattle. Pa. Agr. Exp. Sta. Bul. 452.

Forbes, R. M. and W. P. Garrigus. 1949. The digestibility and metabolizability by lambs of a standard ration of alfalfa and corn and one containing cottonseed hulls. J. Agr. Res. 78:483.

Fraps, G. S. 1914. Digestion experiments with Texas feeding stuffs. Texas Agr. Exp. Sta. Bul. 166.

Fraps, G. S. 1924. Digestion experiments with oat by-products and other feeds. Texas Agr. Exp. Sta. Bul. 315.

Gerlaugh, P. 1928. Cattle feeding experiments 1927-28, shelled corn, ground shelled corn, and corn-and-cob meal. Ohio Agr. Exp. Sta. Bimo. Bul. 135:201

Gerlaugh, P. and H. W. Rogers. 1936. Corn-and-cob meal versus shelled corn for fattening yearlings and calves. Ohio Agr. Exp. Sta. Bimo. Bul. 179:35.

Glendening, B. L., W. G. Schrenk, D. B. Parrish and E. F. Smith. 1952. Mineral content of certain cattle feeds used in North Central Kansas. J. Animal Sci. 11:516.

Gullickson, T. W., F. C. Fountaine and J. B. Fitch. 1942. Various oils and fats as substitutes for butterfat in the ration of young calves. J. Dairy Sci. 25:117.

Hussain, A., A. Halim and A. Wahhab. 1951. Chemical composition and the feeding value of cottonseed hulls. J. Agr. Sci. 41:379.

Jacobson, N. L., C. Y. Cannon and B. H. Thomas. 1949. Filled milks for dairy calves. I. Soybean oil versus milk fat. J. Dairy Sci. 32:429.

Jones, J. H., R. E. Dickson, J. K. Riggs and J. M. Jones. 1942. Silage and cottonseed meal for fattening yearlings. Texas Bul. 622.

King, F. G. 1938. Cattle feeding 1937-38. Part II. The value of a ration containing ground ear corn and shelled corn. Purdue Agr. Exp. Sta. Bul. 433.

King, F. G. 1940. Cattle feeding tests for 1938-39 and 1939-40, comparing shelled corn and corn-and-cob meal. Purdue Agr. Exp. Sta. Mimmeo. 11-39:435 and 11-40:563.

Kleiber, M., H. Goss and H. R. Guilbert. 1936. Phosphorus deficiency metabolism and food utilization in beef heifers. J. Nutr. 12:121.

Klosterman, E. W., L. E. Kunkle, O. G. Bentley and W. Burroughs. 1953. Supplements to poor quality hay for fattening cattle. Ohio Agr. Exp. Sta. Res. Bul. 732.

Lindsey, J. B., C. L. Beals and P. H. Smith. 1917. Digestion experiments with sheep. Mass. Agr. Exp. Sta. Bul. 181.

Lofgreen, G. P. and M. Kleiber. 1953. The availability of the phosphorus in alfalfa hay. J. Animal Sci. 12:366.

Lucas, H. L. and J. K. Loosli. 1944. The effect of fat upon the digestion of nutrients by dairy cows. J. Animal Sci. 3:3.

Matsushima, J. and T. W. Dowe. 1953. Use and value of beef tallow for fattening cattle. Feed Age 3(9):34.

Melton, A. A., N. B. Willey, H. H. Jones and P. J. Lyerly. 1950. Ground cotton stalks, ground gin trash and cottonseed hulls in rations for growing yearling steers. Texas Agr. Exp. Sta. Prog. Rep. 1277.

Moore, W. B. 1951. Demand for cottonseed hulls. Cotton Gin and Oil Mill Press. 52(22):16.

Mumford, H. W. 1905. Comparison of methods of preparing corn and clover hay for fattening steers. Ill. Agr. Exp. Sta. Bul. 103.

Otis, D. H. 1904. Experiments with hand-fed calves. Kan. Agr. Exp. Sta. Bul. 126.

Peters, W. H. 1933. Selection and purchase of feeders and rations for fattening beef cattle. Minn. Agr. Exp. Sta. Bul. 300.

Phillips, P. H. 1952. Trace minerals in livestock feeding. Flour and Feed 53(5):14.

Richardson, D., E. F. Smith and R. F. Cox. 1953. Supplementing wheat straw in the wintering rations of beef calves. Kan. Agr. Exp. Sta. Res. Cir. 297.

Riddell, W. H., J. S. Hughes and J. B. Fitch. 1934. The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Kan. Agr. Exp. Sta. Tech. Bul. 36.

Shrewsbury, C. L., F. N. Andrews, C. Harper and M. R. Zelle. 1943. The value of alfalfa and certain of its fractions in the nutrition of breeding ewes. J. Animal Sci. 2:209.

Snedecor, C. W. 1946. Statistical Methods. The Iowa State College Press, Fourth Edition.

Starkey, L. V. and E. G. Godbey. 1937. Cottonseed hulls compared with corn stover as roughage for fattening steers. S. C. Exp. Sta. 50th Ann. Rep.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The effect of dietary fat on utilization of the energy and protein of rations by sheep. J. Animal Sci. 7:475.

Swift, R. W., R. L. Cowan, G. P. Barron, K. H. Maddy and E. C. Grose. 1951. The effect of alfalfa ash upon roughage digestion in sheep. J. Animal Sci. 10:434.

Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. J. Animal Sci. 6:432.

Tefft, C. W. 1954. The effect of alfalfa ash and certain of its mineral constituents on the utilization of cottonseed hulls by sheep. Master's Thesis. Okla. Agr. and Mech. Col.

Thalman, R. R. and R. B. Cathcart. 1934. Digestion studies on grinding snapped, ear, and shelled corn for yearling steers. Neb. Tech. Cir. 144.

Tillman, A. D., C. F. Chappel, R. J. Sirny and R. MacVicar. 1954 a. The effect of alfalfa ash upon the digestibility of prairie hay by sheep. J. Animal Sci. 13:417.

Tillman, A. D. and R. MacVicar. 1955. The effect of alfalfa ash upon the digestibility of wheat straw by sheep. Okla. Agr. and Mech. Col. Misc. Pub. MP-43.

Tillman, A. D., R. J. Sirny and R. MacVicar. 1954 b. The effect of alfalfa ash upon the digestibility and utilization of cottonseed hulls by sheep. J. Animal Sci. 13:726.

Vaughan, H. W. 1927. Rations for fattening baby beeves and selection of calves for baby beef production. Minn. Agr. Exp. Sta. Bul. 237.

Weber, A. D., C. W. McCampbell, J. S. Hughes and W. J. Peterson. 1940. Calcium in the nutrition of the fattening calf. Kan. Agr. Exp. Sta. Tech. Bul. 51.

Willey, N. B., J. K. Riggs, R. W. Colby, O. D. Butler, Jr. and R. Reiser. 1952. The influence of level of fat and energy in the ration upon feed lot performance and carcass composition of fattening steers. J. Animal Sci. 11:705.

Woodman, H. E. and R. E. Evans. 1930. Nutritive value of pasture. VI. The utilization by sheep of mineral deficient herbage. J. Agr. Sci. 20:587.

APPENDIX

TABLE I

WEIGHT, FEED INTAKE, FEED EFFICIENCY AND
CARCASS GRADES FOR EXPERIMENT I

(82-Day Trial)

Lamb No.	Starting Weight	Daily Gain	Daily Feed Intake	Feed Eff.	Carcass Grade
	(lb)	(lb)	(lb)		
(Individually-penned and Individually-fed)					
38	57.0	0.36	3.3	11.1	Top Good
49	55.0	0.23	2.7	7.9	Low Good
62	56.5	0.38	3.5	9.2	Top Good
65	55.5	0.36	3.9	10.7	Low Good
68	56.0	0.30	2.9	9.6	Low Good
76	55.0	0.34	3.0	8.6	Average Good
90	56.0	0.32	2.9	8.9	Top Good
103	57.0	0.28	3.2	11.4	Top Good
Ave.	56.0	0.33	3.2	9.5	
(Group-penned and Group-fed)					
14	55.5	0.12			Low Good
45	56.0	0.52			Average Choice
50	56.0	0.43			Low Good
58	57.0	Removed from Experiment Due to Urinary Calculi			
73	55.0	0.42			Top Good
87	56.0	0.47			Average Good
86	56.0	0.34			Top Good
122	55.0	0.38			Top Good
Ave.	55.9	0.38	3.2	8.6	

TABLE II

WEIGHT AND FEED INTAKE FOR EXPERIMENT II, TRIAL 1

Ration No.	Lamb No.		28-day Depletion Period: Starting Weight	Daily Gain	Daily Feed Intake	35-day Repletion Period: Starting Weight	Daily Gain	Daily Feed Intake
			(lb)	(lb)	(lb)	(lb)	(lb)	(lb)
1	111		56.0	0.00	1.54	56.0	-0.16	1.41
1	91		63.0	-0.11	1.29	60.0	-0.10	1.42
1	28		66.0	0.00	1.43	66.0	-0.19	1.44
1	35		53.0	0.00	1.07	53.0	-0.11	1.29
		Ave.	59.5	-0.03	1.33	59.5	-0.14	1.39
2	39		61.5	-0.23	1.64	55.0	-0.06	1.61
2	9		60.5	-0.05	1.43	59.0	-0.21	1.56
2	1		69.0	-0.25	1.29	62.0	-0.01	1.65
2	47		60.5	-0.02	1.71	60.0	-0.01	1.63
		Ave.	62.9	-0.14	1.52	59.0	-0.07	1.61
3	95		61.5	-0.09	1.50	59.0	-0.13	1.36
3	55		59.5	-0.02	1.50	59.0	-0.20	1.56
3	101		66.5	-0.16	1.54	62.0	0.03	1.64
3	26		62.5	-0.34	1.36	53.0	-0.06	1.39
		Ave.	62.5	-0.15	1.48	58.2	-0.09	1.49
4	10		58.0	-0.07	1.07	56.0	-0.20	1.60
4	60		70.0	-0.25	1.21	63.0	-0.06	1.61
4	83		70.0	-0.07	1.36	68.0	-0.17	1.60
4	15		63.0	-0.07	1.43	61.0	0.13	1.69
		Ave.	65.3	-0.12	1.27	62.0	-0.07	1.63

(Continued)

TABLE II (Continued)

Ration No.	Lamb No.		28-day Depletion Period Starting Weight (lb)	28-day Depletion Period Daily Gain (lb)	28-day Depletion Period Daily Feed Intake (lb)	35-day Repletion Period Starting Weight (lb)	35-day Repletion Period Daily Gain (lb)	35-day Repletion Period Daily Feed Intake (lb)
5	98		60.0	-0.11	1.50	57.0	-0.16	1.72
5	114		63.0	-0.11	1.39	60.0	0.03	1.69
5	68		66.0	-0.07	1.14	64.0	-0.10	1.48
5	72		64.0	0.00	1.43	64.0	-0.06	1.71
		Ave.	63.3	-0.07	1.37	61.3	-0.07	1.65
6	92		62.0	-0.18	1.21	57.0	0.03	1.61
6	104		59.0	-0.04	1.68	58.0	0.11	1.53
6	115		65.0	-0.07	1.43	63.0	-0.14	1.59
6	48		56.0	-0.11	1.43	53.0	-0.17	1.55
		Ave.	60.5	-0.10	1.44	57.8	-0.04	1.57
7	74		57.5	-0.09	1.64	55.0	-0.23	0.98
7	37		60.0	-0.04	1.46	59.0	-0.31	1.02
7	22		68.0	-0.14	1.57	64.0	-0.23	1.03
7	8		64.5	-0.05	1.71	63.0	-0.31	0.96
		Ave.	62.5	-0.08	1.60	60.3	-0.27	1.00
8	57		60.0	-0.18	1.36	55.0	0.17	1.71
8	24		67.0	-0.18	1.43	62.0	0.09	1.70
8	11		65.0	-0.07	1.54	63.0	0.04	1.71
8	79		61.0	-0.11	1.43	58.0	-0.03	1.69
		Ave.	63.0	-0.13	1.44	59.5	0.07	1.70

TABLE III

WEIGHT, FEED INTAKE, FEED EFFICIENCY AND CARCASS DATA
FOR EXPERIMENT II, TRIAL 2

(97-Day Trial)

Ration	Lamb No.	Starting Weight (lb)	Daily Gain (lb)	Daily Feed Intake (lb)	Feed Eff.	Dressing Percentage	Federal Grade
Basal	39	61.0	0.43			54.4	High Good
	26	59.0	0.38			53.1	High Good
	101	71.0	0.40			57.3	High Choice
	104	70.0	0.47			57.8	High Good
	560	64.0	0.37			52.0	Average Good
	72	69.0	0.40			55.6	High Good
	115	66.0	0.42			54.2	High Good
	Ave.	65.7	0.41	3.87	9.44	54.9	
Basal + Trace Minerals	57	61.0	0.43			53.4	Average Good
	10	58.0	0.38			51.9	Average Good
	11	71.0	0.32			54.9	Low Choice
	15	72.0	0.31			54.9	High Choice
	74	64.0	0.44			54.2	Low Choice
	120	67.0	0.40			53.8	Low Choice
	9	66.0	0.53			58.1	High Choice
	Ave.	65.6	0.40	3.58	8.95	54.5	
Basal + Major Minerals	48	60.0	0.53			56.8	Low Choice
	28	58.0	0.60			53.4	Average Choice
	95	71.0	0.47			53.8	Average Choice
	1	73.0	0.42			56.1	High Choice
	55	63.0	0.42			53.8	High Good
	79	67.0	0.31			56.7	Low Choice
	562	69.0	0.44			52.7	Average Choice
	Ave.	65.9	0.46	3.81	8.28	54.8	

(Continued)

TABLE III (Continued)

Ration	Lamb No.	Starting Weight (lb)	Daily Gain (lb)	Daily Feed Intake (lb)	Feed Eff.	Dressing Percentage	Federal Grade
Basal +	8	63.0	0.53			57.6	High Good
Synthetic	22	57.0	0.52			54.9	Average Choice
Alfalfa	60	70.0	0.54			53.3	Average Choice
Ash	24	70.0	0.51			55.5	Low Choice
	428	62.0	0.39			58.0	High Good
	114	69.0	0.49			56.4	Average Choice
	527	68.0	0.35			57.8	High Good
	Ave.	65.6	0.48	4.04	8.42	56.2	

TABLE IV

WEIGHT, FEED INTAKE AND FEED EFFICIENCY
FOR EXPERIMENT III, PART A, TRIAL 1

(62-Day Trial)

Ration	Lamb No.		Starting Weight	Daily Gain	Daily Hull Intake	Feed Eff.
			(lb)	(lb)	(lb)	
Basal	449		76.0	0.16		
	443		79.0	0.34		
	429		51.0	0.32		
	564		59.0	0.20		
	426		62.0	0.36		
	439		68.0	0.13		
		Ave.	65.8	0.25	1.48	8.25
Basal + Corn Oil	440		72.0	0.21		
	445		70.0	0.19		
	431		74.0	0.11		
	437		69.0	0.16		
	423		71.0	0.32		
	446		71.0	0.21		
		Ave.	71.2	0.20	1.63	10.47
Basal + Alfalfa Ash	64		79.0	-0.06		
	444		61.0	0.40		
	438		57.0	0.50		
	97		68.0	0.19		
	442		81.0	0.27		
	427		59.0	0.26		
		Ave.	67.5	0.26	1.50	7.47

(Continued)

TABLE IV (Continued)

Ration	Lamb No.		Starting Weight	Daily Gain	Daily Hull Intake	Feed Eff.
			(lb)	(lb)	(lb)	
Basal + Corn Oil + Alfalfa Ash	435		64.0	0.37		
	552		72.0	0.24		
	433		77.0	0.32		
	123		68.0	0.31		
	447		65.0	0.21		
	430		73.0	0.16		
		Ave.	69.8	0.27	1.63	7.77

TABLE V

WEIGHT, FEED INTAKE AND FEED EFFICIENCY
FOR EXPERIMENT III, PART A, TRIAL 2

(36-Day Trial)

Ration	Lamb No.		Starting Weight	Daily Gain	Daily Feed Intake	Feed Eff.
			(lb)	(lb)	(lb)	
Basal	22		60.0	0.39		
	23		60.0	0.33		
	34		58.0	0.31		
	424		100.0	0.42		
		Ave.	69.5	0.36	2.94	8.17
Basal + Corn Oil	2		62.0	0.18		
	3		60.0	0.21		
	68		88.0	0.14		
	4		62.5	0.17		
		Ave.	68.1	0.18	2.21	12.28
Basal + Corn Oil + Alfalfa Meal	27		52.5	0.07		
	32		66.0	0.06		
	24		76.5	0.56		
	100		80.0	0.25		
		Ave.	68.8	0.24	2.51	10.46
Basal + Corn Oil + Alfalfa Ash	33		61.0	0.17		
	7		67.0	0.22		
	432		95.0	0.14		
	20		60.5	0.29		
		Ave.	70.9	0.21	2.56	12.19

TABLE VI

APPARENT DIGESTION COEFFICIENTS OF THE
OKLAHOMA A. AND M. BASAL RATION

Period 1

Ration	Lamb No.		Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	34		61.9	34.1	33.3	48.3	74.5	63.1
	46		62.4	47.5	44.4	48.2	73.7	64.1
	38		65.0	60.0	33.3	51.3	74.9	67.0
	120		64.6	47.7	-22.2	48.6	77.3	66.3
		Ave.	63.5	47.3	22.2	49.1	75.1	65.1
Basal + Corn Oil	49		64.7	43.0	87.6	53.4	73.8	66.3
	35		64.8	43.7	88.7	52.8	73.3	66.0
	97		66.1	45.2	88.7	55.6	75.8	68.3
	48		61.3	54.7	90.2	55.3	71.6	65.8
		Ave.	64.4	46.7	88.8	54.3	73.6	66.6
Basal + Alfalfa Ash	39		63.9	41.0	22.2	50.3	77.5	68.5
	100		60.3	43.8	38.9	43.6	75.3	63.7
	25		52.1	36.8	-00.7	31.9	76.4	60.0
	43		64.7	46.7	-00.2	49.2	80.0	67.9
		Ave.	60.3	42.1	15.1	43.8	77.3	65.0
Basal + Corn Oil + Alfalfa Ash	123		71.0	55.7	95.8	59.8	80.2	73.4
	30		64.6	45.9	91.2	49.2	76.5	67.2
	45		66.7	40.9	94.3	54.1	73.4	66.4
	29		67.7	48.9	90.5	60.8	74.8	69.5
		Ave.	67.5	47.9	93.0	56.0	76.2	69.1

TABLE VII

APPARENT DIGESTION COEFFICIENTS OF THE
OKLAHOMA A. AND M. BASAL RATION

Period 2

Ration	Lamb No.	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	440	63.5	42.1	-55.0	36.2	76.0	64.6
	564	67.6	51.3	-88.0	49.0	77.1	68.2
	444	65.3	48.5	-111.0	55.8	73.0	66.7
	Ave.	62.7	47.3	-84.7	47.0	75.4	66.5
Basal ≠ Corn Oil	442	68.1	54.5	92.3	49.6	75.6	69.0
	439	63.9	49.9	92.7	40.3	73.8	65.1
	437	71.2	56.4	92.0	62.4	70.2	68.2
	Ave.	67.7	53.6	92.3	50.8	73.2	67.4
Basal ≠ Alfalfa Ash	438	70.2	51.0	00.3	52.8	81.9	72.6
	435	68.1	53.0	-84.4	53.2	76.9	69.1
	447	67.5	49.7	-20.0	55.2	77.9	70.1
	Ave.	68.6	51.2	-34.7	53.7	78.9	70.6
Basal ≠ Corn Oil ≠ Alfalfa Ash	429	58.7	44.8	94.2	28.7	67.8	59.3
	423	61.8	40.5	90.5	31.2	75.8	63.7
	Ave.	60.3	42.7	92.4	30.0	77.3	61.5

TABLE VIII

APPARENT DIGESTION COEFFICIENTS OF THE
MISSOURI BASAL RATION

Period 1

Ration	Lamb No.	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	24	54.0	55.1	79.4	60.7	46.8	54.0
	41	59.0	62.9	81.8	62.3	53.4	58.6
	44	48.9	51.6	64.7	54.2	43.3	49.1
	64	54.1	55.8	69.1	56.6	53.1	55.1
	Ave.	54.0	56.4	73.8	58.5	49.2	54.2
Basal + Corn Oil	23	52.8	56.4	90.5	52.5	51.7	54.5
	32	47.4	51.9	87.1	49.0	44.5	49.3
	26	49.6	53.5	85.3	50.5	47.5	51.3
	33	50.5	49.9	82.7	51.6	50.7	52.5
	Ave.	50.1	52.9	86.4	50.9	48.6	51.9
Basal + Alfalfa Ash	27	52.3	55.3	85.3	51.1	52.2	52.4
	42	53.0	54.7	64.7	53.7	53.7	53.9
	63	54.6	53.8	79.4	54.1	55.3	54.8
	31	54.6	54.6	75.0	56.3	53.6	55.1
	Ave.	53.6	54.6	76.1	53.8	53.7	54.1
Basal + Corn Oil + Alfalfa Ash	51	56.4	56.2	93.0	56.9	54.0	57.3
	40	55.4	55.3	92.8	54.4	55.6	56.8
	37	54.5	55.8	89.9	60.6	47.9	56.0
	33	53.4	52.7	95.9	52.8	54.1	55.0
	Ave.	54.9	55.0	92.9	56.2	52.9	56.3

TABLE IX

APPARENT DIGESTION COEFFICIENTS OF THE
MISSOURI BASAL RATION

Period 2

Ration	Lamb No.		Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Organic Matter
Basal	443		42.9	50.8	-19.6	27.4	51.6	43.0
	445		52.4	61.4	-13.6	47.9	53.8	52.4
		Ave.	47.7	56.1	-16.6	37.7	52.7	47.7
Basal + Corn Oil	433		61.6	69.0	73.1	59.2	63.4	63.4
	64		52.1	61.6	87.3	49.9	53.3	55.0
	426		53.5	61.8	79.5	50.0	53.7	55.0
		Ave.	55.7	64.1	80.0	53.0	56.8	57.8
Basal + Alfalfa Ash	552		61.0	68.7	-57.1	47.7	67.7	61.2
	431		61.4	68.4	-60.7	47.0	68.7	61.5
	123		59.5	67.2	-32.1	48.4	65.2	60.0
		Ave.	60.6	68.1	-50.0	47.7	67.7	60.9
Basal + Corn Oil + Alfalfa Ash	446		58.6	64.8	78.0	44.5	66.1	60.1
	430		58.5	66.2	81.0	44.6	65.5	60.2
	449		64.3	71.8	79.0	57.7	67.4	65.7
		Ave.	60.5	67.6	80.0	48.9	66.3	62.0

TABLE X

APPARENT DIGESTION COEFFICIENTS OF THE
GROUND CORNCOB BASAL RATION

Period 1

Ration	Lamb No.		Dry Matter	Organic Matter
Basal	76		73.9	75.9
	69		72.8	74.7
	90		74.2	75.5
		Ave.	73.6	75.4
Basal + Corn Oil	57		67.2	68.6
	92		65.1	66.9
	55		68.1	70.2
		Ave.	66.8	68.6
Basal + Alfalfa Ash	97		74.3	77.4
	51		74.2	77.2
	91		73.1	76.1
		Ave.	73.9	76.9
Basal + Corn Oil + Alfalfa Ash	85		73.8	77.1
	68		74.0	76.7
	88		72.7	75.7
		Ave.	73.5	76.5

TABLE XI

APPARENT DIGESTION COEFFICIENTS OF THE
GROUND CORNCOB BASAL RATION

Period 2

Ration	Lamb No.		Dry Matter	Organic Matter
Basal	55		66.0	67.5
	92		65.4	67.4
	97		72.1	74.1
		Ave.	67.8	69.7
Basal ≁ Corn Oil	57		63.2	64.9
	88		60.0	60.8
		Ave.	61.6	62.9
Basal ≁ Alfalfa Ash	68		68.9	75.6
	90		73.6	78.8
	69		73.7	78.0
		Ave.	72.1	77.5
Basal ≁ Corn Oil ≁ Alfalfa Ash	91		71.4	75.1
	76		72.6	77.6
	85		70.2	76.6
		Ave.	71.4	76.4

VITA

John K. Ward

Candidate for the Degree of

Master of Science

Thesis: FACTORS AFFECTING DIGESTIBILITY AND UTILIZATION OF LOW QUALITY ROUGHAGES BY SHEEP

Major: Animal Husbandry

Biographical:

Born: July 1, 1927, at Litchfield, Nebraska.

Undergraduate Study: McPherson College, McPherson, Kansas, 1946-1950; Kansas State College, Manhattan, Kansas, 1953-1954.

Graduate Study: Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma, 1954-1956.

Experience: Farming; Graduate Assistant in Animal Husbandry.

Date of Final Examination: January, 1956.

THESIS TITLE: FACTORS AFFECTING DIGESTIBILITY AND UTILIZATION OF LOW QUALITY ROUGHAGES BY SHEEP

AUTHOR: John K. Ward

THESIS ADVISER: Dr. A. D. Tillman

The content and form have been checked and approved by the author and thesis adviser. The Graduate School Office assumes no responsibility for errors either in form or content. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Mrs. Bonnie Ward