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CORN

PREPARATION

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*Approved Howard Hadedorn
May 15-1916*

CORN PREPARATION FOR FATTENING LAMBS.

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SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the

GRADUATE SCHOOL

of the

UNIVERSITY OF MISSOURI

1916

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Part I

Corn Preparation for Fattening Lambs.

The question of the advisability of grinding grain for farm animals is one which is causing a great deal of discussion at the present time. Theoretically it would be expected that any preparation of a feed, for any class of farm animals, which would render mastication easier and simpler, would result in a higher coefficient of digestion for that particular feed, and would consequently enhance its feeding and fattening qualities. The work which has been done at the different Experiment Stations in the United States, as well as the opinions of some of our foremost authorities on the value of preparing grain for the different classes of live stock, will be reviewed first.

The Preparation of Corn for Hogs.

The West Virginia Experiment Station* reports the results obtained from feeding whole and ground corn to fattening hogs. Stewart and Atwood, the authors of the Bulletin, have summarized all of the experimental work along this line which had been done prior to the year 1899. The following table gives a resumé of this work.

* Bul. 59

Experiment. Where Per- formed.	No. of Animals Fed.	Average Initial Wt.	Daily Gain		Total Grain		Total Gain		Feed per		No. of
			Lbs.		Eaten		Lbs.		100 Lbs.		Days
					Lbs.				Gain.		Fed.
			Lbs.								
			Corn	Corn	Corn	Corn	Corn	Corn	Corn	Corn	
			Meal	Meal		Meal	Lots	Meal	Meal	Meal	
Alabama (Canebrake)	4	79	.75	1.4	292	397.5	63.5	122	459	325	42
Maine Sta.	6	164	1.07	1.0	1272	1272	271	252	469	504	84
New York (Geneva)	8	111	--	---	Equal Quan- tities.		174	252	---	---	---
Kentucky	4	100	1.44	1.39	780	753	182	175	429	430	63
Missouri	8	155	1.90	2.04	2864	3196	594	638	482	501	--
Ohio	6	202	1.20	1.14	2039	2116	404	383	505	552	--
W. Virginia	6	223	1.67	2.38	819	951	141	199	579	475	28
W. Virginia	12	95	1.65	1.73	2138	2384	555	581	385	410	56

In conclusion Stewart and Atwood state, "The average of the twelve experiments, in which the amount of feed required for 100 pounds gain in live weight is given, shows that 505 pounds of corn and 472.9 pounds of corn meal were required for 100 pounds of gain, or in other words, in these experiments it required about 6 per cent less corn to produce 100 pounds gain when it was ground than when it was fed unground.

The average of these different experiments and our own results indicate that unless a farmer is located very close to a mill, or has one upon his own farm, that, as a rule, it will not pay to grind corn for hogs."

At the Colorado Station* Cooke carried on a test with young pigs to determine the advantage of grinding barley and corn over feeding these grains whole. The essential results obtained are presented in the following table.

	No. of tri- als.	Av. Ini- tial Wt.	Av. Daily Gain	Av. Daily Feed		Feed per pound Growth.	
				Grain lbs.	Skim- milk qts.	Grain lbs.	Skim- milk qts.
Whole Corn	6	63	.44	1.9	1.0	6.7	1.2
Ground Corn	6	62	.52	2.4	.8	5.8	.9
Whole Bald Barley	4	58	.65	2.0	1.8	3.7	1.8
Whole Ground Barley	4	60	.77	2.3	1.0	3.2	1.0
Whole Common Barley	3	43	.44	1.9	.7	5.2	.9
Ground Common Barley	3	43	.47	1.9	.7	4.7	.9

Cooke says in conclusion, "In almost every case the ground grain has given better results than the unground. This is most noticeable in the case of ground corn. The little pigs weighing but 25 pounds each made but small headway eating whole corn, and gained but the tenth of a pound per head per day. The older pigs had no trouble in masticating the grain, but their growth is still somewhat slower than those fed on ground grain, and required more food to produce a pound of growth.

"Ground bald barley made a better growth than the unground. To one who watched the experiment, the wonder is that

*Bulletin 40

the results are not still more in favor of the ground grain. Bald barley is smooth and very hard; harder than the hardest wheat. A large part of it, when fed unground, passes through the alimentary canal whole and undigested. In the course of the day these grains would be again and again eaten from the floor of the pen. It is possible that the same grain passed through a pig from three to five times. Each time some of the grain would be cracked and digested. The small difference in the results of the ground and unground, would seem to indicate that eventually most of the grain was digested but the pigs certainly earned all they ate."

Opposite results were found to be true with sheep. "For the whole season the average is two pounds per head in favor of the whole grain. Thus the grinding of the grain was not only time and labor lost, but was an actual detriment to the sheep. Whole grain yielded more rapid and cheaper growth than ground grain."

The results of ten years of experimenting with whole corn and corn meal for pigs is published in a bulletin from the Wisconsin Station*. Concerning these results, Mr. Henry, who conducted the trial, says, "For the past ten years this Station has been testing the value of feeding whole corn in comparison with corn meal, as the main portion of the ration for fattening pigs. During this period, 18 trials have been made and the results published from year to year. The totals

*Bulletin 45.

and averages for the ten years show that the 140 pigs receiving shelled corn as the principal ration, ate 47,736 pounds of shelled corn and 22,590 pounds of middlings, or a total of 69,326 pounds of grain on which they made 13,828 pounds of gain.

"The 140 pigs receiving corn meal as the principal ration ate 50,647 pounds of corn meal and 24,189 pounds of middlings, or a total of 74,836 pounds of grain, on which they made 15,891 pounds of gain.

"The 140 pigs receiving the corn meal ate 5510 pounds more grain and made 2036 pounds more gain than the 140 pigs receiving shelled corn. The pigs receiving shelled corn consumed an average of 501 pounds of grain for each 100 pounds gain. The pigs receiving the corn meal consumed an average of 471 pounds of grain per 100 pounds gain, thus producing 100 pounds gain on 30 pounds less grain than the pigs receiving shelled corn. In the 18 trials there were 11 that showed a saving by grinding, the amount saved varying from 2.5 per cent to 18.5 per cent. There were seven trials when there was a loss from grinding, the amount lost varying from 1.1 per cent to 11.1 per cent. The average of 18 trials shows a saving from grinding corn of about 6 per cent. The economy of grinding corn will depend on the price of corn and the price of grinding. Where there is plenty of time for maturing the pigs, and it is not necessary to secure the maximum daily gain, it is doubtful if it pays to grind corn for pigs. On the other hand, when fitting hogs for show, sale, or in high pressure feeding for market, the feeder will consider it advisable to grind the corn, even though it is ex-

pensive to do so."

Bliss and Lea, of the Nebraska Station*, report the results of feeding trials with ground and whole wheat for 135 pound pigs. In a twelve weeks trial, it was found that a net profit of 21 cents per bushel resulted from grinding wheat over feeding it whole. Four cents per bushel was allowed as the cost of grinding. In the summary and conclusions, the authors state in part, "3 pounds of soaked ground wheat produced as much gain as four pounds of soaked whole wheat. Ground wheat at \$1.00 a bushel proved as economical as whole wheat at 75 cents a bushel. Ground wheat produced gains 42 per cent faster than whole wheat."

At the Indiana Experiment Station**, King conducted an extensive trial with grinding and shelling corn for pigs. Concerning the results of his work, King says, "The thoro and systematic trials conducted at the University of Wisconsin and reported in Bulletin 145 seem to show beyond a doubt that so far as rate of gain and economy of feed is concerned, ground corn is more efficient than shelled corn but from a financial standpoint the cost of grinding and the relative costs of the feeds are the determining factors. Later experimental data secured at the Iowa Station and reported in Bulletin 106, present evidence contrary to the Wisconsin results. These later trials introduced the factor of the size of the hogs but do not so connect the rations fed that a direct comparison may be drawn between the results of these two prominent Experiment Stations. It was with the idea of obtaining additional evidence on the influence of size of hog on the effect of prepar-

*Bulletin 144

**Bulletin unpublished. Reported in the proceedings of the American Society of Animal Production, 1913.

ation of corn and to properly connect the experimental results gathered at other Stations, that the study of preparation of corn for hogs was undertaken at the Purdue Experiment Station.

* * * These data show that if young hogs are started at 150 pounds, ground corn will produce more rapid gains upon a somewhat smaller quantity of feed, than either ear corn or shelled corn." Commenting further on this work, Henry and Morrison, in their "Feeds and Feeding," state, During the first and second months there was no appreciable benefit from shelling corn or from grinding it. In the third month the pigs fed ground corn began to make slightly larger gains, and required a little less feed for 100 pounds gain. When the pigs reached a weight of 140 pounds the difference became slightly more marked. During each of the last three months the pigs fed ground corn ate more feed, made slightly more rapid gains, and required less feed for 100 pounds gain. For these months the saving by grinding, however, was not large, amounting to only 4.1 per ct. on the average over ear corn. Ear corn gave slightly better results than shelled corn. The slightly more rapid and more economical gains of the older pigs on ground corn were probably due to the fact that as pigs mature and fatten, they masticate corn less thoroly. This is shown by digestion experiments conducted by Evvard at the Iowa Station with 60 and 200 pound pigs."

At the Iowa Station* a test was carried on with 312 hogs of all ages fed in 32 lots. Six forms of corn were tested;

* Bulletin 206.

dry ear corn, soaked shelled corn, dry corn meal, soaked corn meal, and soaked corn and cob meal. Kennedy and Robbins, who made the test, state, "Dry ear corn was fed with the least waste and in 1907 made the fastest gain. The pigs ate it more slowly than soaked corn, owing to the greater time required to masticate it. The average results for two years show that for spring pigs during their first summer and fall, there is a saving of over six per cent by feeding it in the ear instead of shelling and soaking it, and a saving of 18 per cent to 24 per cent by feeding it in the ear instead of shelling and grinding it. The small savings of corn by grinding it are insignificant because in every case where there was any saving by grinding a still greater saving was effected by simply soaking the shelled corn for twelve hours in water. In general the fastest and most economical gains were secured by feeding dry ear corn until the hogs were close to 200 pounds in weight. For hogs above 200 pounds in weight, soaked shelled corn, while a trifle slower in rate of gain than soaked corn meal, made the most economical gains of all the forms in which corn was fed."

At the Vermont Station* Hills gives the results of a test carried on with fifty pound pigs to determine the advantage of feeding ground corn over whole corn. He says, "Corn meal was found to have a slightly greater feeding value than whole corn, not enough, however, to, as a rule, pay for the cost of grinding."

In a work published in 1892, Robertson, of the Canada Central Experiment Station**, gives the results of a feeding trial with 70 pound pigs in two lots of five each. It was found that

* Annual Report, 1895.

** Bulletin No. 15.

"A ration of equal parts of peas, barley, and rye not ground produced a pound of gain for 4.45 pounds of grain fed, and when the grain was ground, 4.36 pounds were required for a pound of gain."

Practically all of the results of experimental work which has been done on the subject of grinding corn or other grains for hogs show that ground corn has produced a greater and more rapid gain than has whole corn, but in few instances has the increase been sufficient to overcome the cost of grinding. An exception to this rule may be found under such conditions as the Purdue Station reports, where it might be advantageous to grind corn for very heavy hogs or fat hogs toward the close of the feeding period.

Little work has been done to determine the value of preparation of corn for cattle. Among the publications which have been issued, giving an attempted solution of this problem, is a circular from the Indiana Station*. In this work Skinner and Cochel decided to get the opinions of the practical cattle feeders themselves on the subject; accordingly a list of questions was submitted to each of about 2500 farmers. One of these questions was, "How do you feed your corn? As broken ear? Snapped? Shelled?" etc.

Commenting upon some of the answers received relative to these inquiries, Skinner and Cochel state, "The question of whether or not it is profitable to put a large amount of labor on corn to increase the feeding value is one that is very largely

*Indiana Circular No. 12.

disputed. There were 73 per cent of the feeders who reported the use of broken ear corn, which is about the simplest form in which it can be fed; the next in rank of popularity was feeding shock corn which is used by 46 per cent of the feeders; the next is snapped corn used by 35 per cent; corn and cob meal seems to be next in favor with 27 per cent using it; shelled corn is used by 21 per cent. Other methods of preparation such as soaking or grinding are not very extensively used. About 4 per cent of all who answered this question are soaking their corn and 4 per cent are feeding it in the form of corn meal. This would seem to indicate that the most profitable method is to feed it as broken ear or snapped corn which logically follows with the preference of the feeders for two-year-old cattle. They think that the increased returns due to grinding, soaking, or shelling, are not sufficient to offset the labor in the operation. "

In a similar work at the Missouri Station* where statistics were gathered from practical feeders thruout the State, Waters makes the deduction that little or no attention is paid to the preparation of corn for cattle. In Missouri 53 per cent of the feeders reported feeding ear corn exclusively, while 47 per cent of those from Illinois and 41 per cent of those from Iowa made a similar report. The author states that, "the practical feeder's conclusions are usually right. ---Better preparation of grain is required for young cattle than for aged animals in order to stimulate the most rapid gain. This is necessary to finish the younger animals within a reasonable length of time. They use so

*Bulletin 76.

large a proportion of their food for growth that a high rate of gain is necessary to make them fat quickly.

"The real reason for preparing grain for cattle is not to reduce the proportion of grain passing thru the animal undigested but to increase the rate of gain.

"That feeders consider that they have not found it profitable to put much effort into the preparation of feed is still more strikingly shown by the fact that only 24 Missouri feeders out of a total of 726 reported feeding corn meal; only 4 out of 90 Iowa feeders so reported, whereas none of the 36 Illinois feeders followed the practice. This means that 28 out of 582 or 3.2 per cent of all the feeders interviewed, grind corn as a regular practice, for their cattle.

"It is evident from a study of the detailed answers to our questions in regard to the preparation of feed, and particularly from a study of the summary of these replies just presented that the practice of offering feed of finer texture, better quality, and higher palatability in the latter part of the feeding period than in the earlier part is well established. This is due to the fact that an animal in thin condition has a good appetite and will consume coarse and relatively cheap material in sufficient quantity to make profitable gains. Later, when the system is loaded with fat, the appetite becomes more delicate and discriminating, and requires to be catered to in quality, palatability, and condition, in a marked degree in order that a rapid rate of gain may be maintained and an economical finish be made. This is particularly true of cattle that are to be made very fat

and is more true of young than of old animals on account of the tendency of the former to use much of its feed for growth. In such cases a relatively large gain may show a very slight improvement in the condition of the animals. Therefore a preparation of feed that would be wholly impracticable for the earlier or main portion of the feeding period might prove exceedingly profitable in the last 60 days.

"Better preparation is required in summer than in winter feeding because the grass in summer is more palatable than the roughage used in winter, and for a large consumption of grain to produce a profitable gain, it is required that the grain be palatable. Moreover grain in summer is dry, hard, and more difficult to masticate, and is liable to have been somewhat fouled by mice and rats."

At the Illinois Station* a test was carried on with five lots of 1000 pound choice steers in an effort to determine which method of preparing and feeding corn and clover hay to fattening animals would return to cattle feeders, under varying conditions, the largest profits. In the conclusions, the author of the bulletin states, "In this test more rapid gains were secured with whole than with shelled corn and equally as good as with meal.

"Corn meal proved more efficient for beef production than shelled corn, while for combined beef and pork production, they appear to be about equally efficient.

*Bulletin 103.

"Corn meal is not more efficient for beef production than is ear corn.

"Ear corn is much more efficient for beef production than is shelled corn."

At the Missouri Station * Allison fed five lots of six steers each on a basal ration of cottonseed meal or cottonseed cake, corn silage, and either clover or alfalfa hay. The trials cover three years. In addition to the basal ration, Lot I received broken ear corn; Lot II shelled corn; Lot III crushed corn and cob; Lot IV corn and cob meal; and Lot V corn meal. The average results obtained during the three years trials are presented in the following table:

* Information to the writer.

	Lot.	I	II	III	IV	V.
Av. Initial Wt.	5829.00	5897.80	5839.36	5619.72	5881.89	
Av. Final Wt.	7829.10	8037.60	7883.11	7945.54	8315.17	
Av. Daily Gain	2.86	2.71	2.59-	2.61	3.08	
Rations:						
Broken Ear Corn	17.11					
Shelled corn		17.78				
Crushed Corn and Cob.			16.94			
Corn and Cob Meal				16.82		
Corn Meal					18.33	
Cottonseed Cake*	2.78	2.96	2.75	2.72	3.05	
Corn Silage	17.58	17.75	16.00	16.61	18.22	
Alfalfa Hay**	2.49	2.70	2.53	2.36	3.08	
Pork Produced Lbs.	583.80	408.45	243.39	107.60	115.80	
Value of Pork @ \$8.00 per cwt.	\$44.03	\$32.66	\$19.49	\$8.61	\$9.26	
Beef and Pork Produced per Bu. of Corn Fed*** Lbs.	11.22	9.77	9.70	9.21	9.71	
% Gain in Live Wt. which is beef	77.97	83.90	88.78	95.18	95.38	
% Gain in Live Wt. which is Pork	22.03	16.10	11.22	4.82	4.62	
Selling Price per cwt. \$	8.61	8.68	8.63	8.77	8.93	
Profit per Steer \$	4.60	3.01	1.58	-.52	2.68	

*Cottonseed Meal used in one trial

**Clover Hay used in one trial

*** Average of two trials.

The prices charged for the various feeds used in the rations were as follows:

Average price, three trials

Alfalfa Hay \$14.30 per ton

Corn, (shelled basis) \$.533 per bushel

Corn silage, \$3.66 per ton

Cottonseed Cake, \$27.00 per ton.

As yet Allison has drawn no conclusions from these trials. The data, however, seem to indicate that, from the standpoint of beef production alone, it will pay to grind corn for fattening cattle. The ground corn produced more rapid gains and more uniform gains than corn which had ^{not} been ground. Where the pork produced is taken into consideration, no advantage was found in grinding, as is shown in the table. According to these trials, shelling the corn did not increase its value for producing gains.

A possible advantage of shelling corn for beef cattle is given in Henry and Morrison's "Feeds and Feeding." Quoting from the text, "Good, of the Kentucky Station, (information to the authors) finds that steers fed silage often fail to eat sufficient corn when it is supplied in the form of ear corn, possibly due to the fact that the silage makes their gums tender. By feeding shelled corn, this difficulty is obviated."

From a summary of the work which has been done along this line, it seems that shelling corn does not ^{increase} its feeding value over feeding it whole, to beef cattle. Grinding corn may greatly increase its feeding and fattening value so far as the rate of gain and uniformity of gains are concerned, but where pigs

follow the cattle, it is doubtful if the results warrant the practice of grinding, when the gains of both beef and pork are taken into consideration.

The investigations which have been carried on in an effort to determine the advantage of preparing grain for sheep and lambs are exceedingly few in number. Perhaps the most prominent work along this line has been done by Evvard, at the Iowa Station*. The test was carried on with six lots of 40 range lambs each, averaging 52 pounds per head in weight. All of the lots received a ration of corn in some form; three lots received silage and cottonseed meal in addition to the corn; three lots received alfalfa hay in addition to the corn. The three lots receiving silage and corn meal will not be taken into consideration here. The following table gives the results obtained, for the lots receiving corn and alfalfa hay.

*Information to the writer.

Lot No.	I	II	III
Ration	Broken ear corn, Alfalfa	Shelled corn, Alfalfa	Ground corn, Alfalfa
Initial Weight	2432	2444	2450
Total gain of all lambs	1142	1149	1212
Average daily gain	.264	.266	.281
Average daily feed			
Corn	1.31	1.31	1.31
Alfalfa	1.19	1.19	1.19
Cost of 100 pounds gain	\$6.83	\$6.88	\$6.77
Initial cost of lambs at Ames per CWT.	\$6.25	\$6.25	\$6.25
Shrinkage in shipment per cent	2.35	1.48	4.42
Dressing per cent	51.37	51.44	51.94
Net selling at Ames per CWT.	\$8.36	\$8.44	\$8.18
Profit per lamb	\$1.91	\$1.98	\$1.79

Prices charged for feeds:

Corn a bushel, Broken ear 39¢; Shelled 40¢; Ground 43¢;
Cottonseed Meal \$30.00 per ton; Alfalfa Hay \$15.00 per ton; Corn
Silage \$2.60 per ton. All corn on basis of 56 pounds to the
bushel.

From this work Evvard concludes, first, "That broken ear corn is most efficient for fattening lambs. This is especially true for a short fattening period of from 80 to 90 days. The observations upon these lambs strongly indicated that to get the maximum returns from the corn fed, one should endeavor to 'keep the feed just a little bit better than the lambs.' This really means that one should start on whole or broken ear corn,

and after a month or two when the lambs indicate that they desire shelled corn, it should be given to them largely in that form. Finally when the lambs become quite fat and one wishes to keep them thirty days or so longer, it may be advisable to finish on corn meal. Alfalfa and broken ear corn started out best, then shelled corn seemed to be relatively more efficient, and finally at the close of the experiment, the ground corn lambs forged to the front."

At the Illinois Station * Coffey fed five lots, each of 16 western lambs averaging 65 pounds in weight, clover hay and corn in various forms for 98 days in an effort to find out the most economical method of preparing corn for fattening lambs. His results are presented in the following table.

Lot.	Daily : Gain :	Fed for 100 pounds	
		Corn :	Roughage
I Ear corn 1.6 Lbs. Clover hay			
1.3 Lbs	.293	439**	453
II Shelled Corn 1.3 Lbs. Clover			
hay 1.3 Lbs.	.295	432	449
III Ground Corn 1.3 Lbs. Clover			
hay 1.3 Lbs.	.264	483	505
IV Corn and Cob Meal 1.5 Lbs.			
Clover hay 1.2 Lbs.	.264	489#	475
V Shelled Corn .06 lb. Clover hay			
1.0 lb. Shock corn 2.7 Lbs.	.247	23	406
			1,111***

*Data secured from Henry and Morrison's "Feeds and Feeding".

**Reduced to shelled corn basis

Reduced to shelled corn basis

***Shock corn containing 53 per cent of ears.

Coffey says, "The lambs in Lot II fed shelled corn made the largest and most economical gains. Both ground corn and corn and cob meal produced smaller and more expensive gains than did shelled corn. Ear corn, fed Lot I produced about as large and economical gains as shelled corn. Lot V was fed a small amount of shelled corn until they had learned to husk shocked corn, and thereafter were given corn only in the form of shock corn. These lambs made somewhat lower gains than did the other lots and, including the corn in the shock corn, required 522 lbs of corn for 100 pounds gain. Both ear corn and shock corn are better suited for feeding on a thisk sod than in a dry lot or barn for they may be scattered on the soil so that each lamb will have an equal chance to feed and little will be wasted. In the lot or barn lambs are apt to drop the ears on the ground where they will become soiled or bunch them up so that each lamb does not get its share.

"From these trials we may conclude that it will rarely pay to grind corn for fattening lambs, except where they are fairly fat and it is desired to continue feeding them for some time."

At the Wisconsin Station * Carlyle found that the fineness in grinding grain for lambs influenced the amount of grain eaten and subsequently the gains made. In publishing the results of an investigation to compare the feeding values of corn vs. cow peas as a factor in raising lambs for an early market, Carlyle says, "The lambs in Lot I were fed coarsely

*Report, 1899

ground corn, it having been found from repeated trials that lambs ate of it much more freely when it was coarsely ground than when very fine and powdery."

At the Wyoming Station * Faville fed five lots, each of 24 low grade western lambs averaging about 45 pounds in weight. One phase of the trial was an effort to determine the value of preparing barley. The results of the trial are given in the following table:

Lot No.	Av. Initial Wt.	Av. Final Wt.	Av. Total Gain	Av. Daily Gain	Feed per 100 Lbs. Gain	Av. Daily Ration
					Grain: Hay	Grain : Hay :
I. Shelled Corn Alfalfa Hay	43.1	82.8	39.7	.36	199 746	.72 2.70
II Whole Dry Barley Alfalfa Hay	46.4	83.3	36.9	.34	214 799	" "
III Whole Soaked Barley Alfalfa Hay	44.2	80.3	36.1	.33	219 820	" "
IV. Cracked Barley Alfalfa Hay	43.8	79.5	35.7	.32	221 829	" "
V. Barley Meal Alfalfa Hay	43.1	79.3	36.2	.33	218 812	" "

Faville states in the bulletin, "Feed requirements for all the barley lots were remarkably uniform. Dry whole barley gave slightly the best returns, hence it is safe to assume from results of the foregoing trial, that soaking, grinding or cracking western barley does not increase its value in lamb rations."

Wilson and Skinner, of the South Dakota Station **report the results of trials with grade Shropshire and Hampshire lambs

*Bulletin 103

** Bulletin 80

where ground barley was compared with whole barley and ground wheat with whole wheat. The lambs were fed in an enclosed shed divided into compartments, each compartment opening into a small yard. In reviewing the results of the investigation the authors state, "The lots fed on ground grain did not make as large a gain for the periods as those fed on whole grain. This is especially true during the first part of the experiment. We find that the two lambs (Individual records were kept) making the largest and smallest gains were in Lots 6 and 8, making 60 and 17 pounds respectively. They were practically of the same weight at the beginning of the experiment, but the former made a good gain at the start, and kept it up throughout the experiment, while the latter was very uneven in its gains. We are safe in attributing this difference to the ground grain in the latter lot, for not in a single instance of any of the former lot was there a loss recorded after they got on full feed. But in the latter lot a standstill and loss in their weights will be noted, especially during the first period of the experiment."

The more important results of the experiment are given in the following table.

Lot No. and Ration.	No. of Lambs	Total Gain	Lbs. Grain for 1 lb. gain	Av. Da. Gain	Cost of grain for 1 lb. gain
		lbs.		lbs.	¢
IV Speltz, Native Hay	8	309	5.8	.35	5.8
V Ground Speltz, Native Hay	9	304	6.5	.31	6.5
VII Macaroni Wheat, Bran* Native Hay	9	335	6.0	.34	5.4
VIII. Ground Macaroni Wheat, Bran*, Native Hay	8	274	5.6	.31	5.7

*1/3 Bran to 2/3 Wheat.

In conclusion the authors state, "Grinding grain for lambs was not profitable when fed as a separate ration, as it decreased the palatability and therefore interfered with the gains."

On the general subject of grinding grain for lambs, Henry and Morrison, in their "Feeds and Feeding", state, "Of all farm animals the sheep is best able to do its own grinding, and with few exceptions, whole grain only should be furnished. The common saying of feeders, 'a sheep which cannot grind its own grain is not worth feeding' is a truthful one. Valuable breeding sheep with poor teeth may be continued in usefulness by being fed ground grain. In certain cases, grinding may prove advantageous. At the Colorado Station (Bulletin 32) Cooke, when feeding western sheep on wheat, observed that much of the grain passed thru the animals unbroken, As shown in the next

chapter, it is well to grind such hard seed as bald barley, millet, and screenings containing small weed seeds."

The same authors, on the general subject of feeding ground grain to farm animals, say, "As has been shown before, grinding, crushing or rolling grain increases the digestibility only when animals fail to masticate the whole grain. In fact grinding grain so finely that it is bolted with little chewing may sometimes decrease the digestibility because of imperfect mixture with the saliva. For animals such grains as bald barley or rice, which are unusually hard, or small seeds, such as millet, seed from the sorghums or weed seeds, should ordinarily be ground. For animals with poor teeth or for young animals before their teeth are well developed, grinding grain in general is advisable. ordinarily horses can grind their own oats and corn, and idle horses should always do so. For horses which are hard worked and spend much of their time away from the stable, the grain may well be ground and mixed with a small allowance of moistened chaffed hay. A cow yielding a large flow of milk is a hard worked animal and her grain should usually be ground. Where pigs follow fattening cattle to gather up any grain which escapes mastication and digestion, there is no advantage in grinding corn or even shelling it, except perhaps toward the close of the feeding period when the cattle may be induced to eat more by grinding. Where no pigs run with cattle, it is usually economical to grind or crush the corn before feeding. Except in the case of small or hard seeds, sheep with good teeth should grind their own grain. While

it pays to grind the small grains for pigs, there is no appreciable advantage in grinding corn for pigs weighing 150 lbs. or less. For older animals such preparation may sometimes be profitable."

Jordan, in his book entitled "The Feeding of Animals", says, concerning the general subject of grinding grain, "Few points are more frequently questioned than the profitableness of grinding grain. There seem to be only two ways in which such preparation can enhance the nutritive value of feeding stuff; viz., by diminishing the energy needed for the digestive processes and by increasing the digestibility. While only about a half-dozen experiments bearing on the digestion side of this question are on record, their evidence is quite emphatic. In three trials with horses, with both corn and oats, grinding caused an increase in digestibility varying from 3.3 per cent to 14 per cent. A single experiment with maize kernels gave a greater digestibility of about 7 per cent from grinding and with wheat, in one trial the increase was about 10 per cent. In one test of oats with sheep, the unground kernels were as completely utilized as the ground. It is reasonable to expect that with ruminants the danger of imperfect mastication is less than with horses and swine, altho whole kernels of grain are often seen in the feces of bovines. The profitableness of grinding grain turns, at least in part, upon the relation of the cost of grinding. If the miller's toll amounts to one-tenth of the value of the grain, the economy of grinding it may be doubtful, especially with ruminants."

Woll, in his "Productive Feeding of Farm Animals", writing on the subject of "Grinding, Cutting and Rolling of Feeds," takes the stand that grinding increases digestibility according to the age of the animal the grain is fed to, more than to which class of ruminants or non-ruminants the animal belongs. On this point he says, "The digestibility of feeding stuffs is not, as a general rule, materially altered by special preparation, like cutting, craking, grinding or rolling. An exception to this rule is found in the case of old or very young animals that cannot chew their feed well, and with small hard seeds that would pass thru the digestive tract unbroken and would not be acted upon by the digestive fluids of the body. When used for feeding farm animals, grains like wheat, barley, rye, kafir corn, etc., are therefore usually ground, and other cereals (corn, oats) are ground only when fed to young animals, so as to insure a maximum digestibility. If whole or broken grain reappears in the dung of the animals, it is evident that the feed had better be ground, that too much is being fed, and that the allowance should, in that case, be reduced.

Bailey, in his "Cyclopedia of American Agriculture," Vol. III, P. 69) explains the apparent advantage of grinding grain for some classes of animals as follows: "Extensive experiments with swine have also shown a distinct advantage on the side of the ground feed as measured by the gain in live weight. The explanation of these facts is not far to seek. The seed coats are intended by nature for the protection of the seed,

and consist of relatively soluble resistant substances. When grain is fed whole a varying proportion, according to the size and hardness of the seeds, the amount fed, the species of animals, the condition of its teeth, and other factors, is likely to escape mastication and be swallowed whole. Such seeds, protected by their outer coats, are more or less imperfectly acted on by the digestive fluids, altho we have no satisfactory data as to the extent to which they are thus protected. The loss is likely to be a variable one, altho less with ruminants than with horses and swine, while the question of profitability of grinding involves also the question of cost. In the recorded experiments, the gain from grinding has varied from 3 to 14 per cent. If the cost of grinding amounts to 10 per cent of the value of the grain, its economy for healthy animals may be well doubted."

In summarizing the work which has been done on the subject of grinding grain for farm animals, it may be said that the extent of the profitability of grinding remains to be proved.

CORN PREPARATION FOR FATTENING LAMBS.

It was on account of the scarcity of data concerning the advisability of grinding and shelling corn for fattening lambs that the following experiment was carried on by the writer at the University of Missouri.

Object. The object of this experiment was to determine 1st., which method of preparing corn for fattening lambs will produce the most economical gains in live weight; 2nd., to determine, as far as possible the reasons for any variations in gains should they occur; 3rd., to determine the differences in the digestion coefficients of the various forms of corn fed; 4th., to compare the relation of the amount of water drunk with the gains made and the different methods of preparing corn.

PLAN.

Lots. At this time it was found impossible, on account of the digestion trial to be carried on near the close of the feeding period with the same lambs, to make the investigation concerning feeding values on as large a basis as might be hoped for. Under the existing conditions it was practicable to feed only three lots.

Feeding Quarters. The experiment was conducted in the loft of the sheep barn at the Missouri State Experiment Farm. Individual pens, $3\frac{1}{2}$ feet wide and 5 feet long were constructed from 1" by 4" strips, leaving plenty of space between the boards to enable each lamb to plainly see its neighbors. Two

large windows and a stairway afforded ample ventilation and light. The floor of the pens was kept covered about 5 inches deep with clean straw thruout the feeding trial, except during the digestion trial, when it was removed and the floor kept clean. This was necessary in order to recover any of the feces which might drop on the floor and which would be lost if the straw were allowed to remain.

Exercise was afforded by permitting the lambs to run on the floor of the loft for about half an hour at intervals of two or three days. No exercise was given them during the digestion trial. Some idea of the construction of the pens may be had from the following photograph.

10 The feeding troughs were made from inch lumber. They were two inches wide at the top, six inches wide at the bottom, ten inches deep, and two feet long. A notch eight inches wide and six inches deep was cut in the front of each trough to prevent the loss of grain and hay which might otherwise occur thru the animals tossing their heads.

Lambs. Grade western wether lambs were used in this experiment, all of them of western Merino foundation. They were purchased from J. W. Terrell, a farmer living a few miles out of Columbia, and were selected with special regard to uniformity of size and conformation to type. Collectively they were a rather typical lot of western lambs, altho minor physical differences could be noted.

Lamb No. 1.

Lamb No. 1 was thruout the experiment, the most timid of any of the six animals. In general mutton conformation, it was superior to the others excepting Lamb No. 2, having a very straight back, good spring of ribs, and a deep body. The head, however, lacked some of the qualities necessary toward the making of a superior feeder. The face was rather long and lacked breadth; the nostrils were not as wide as might be wished for and the mouth was inclined to be narrow.

Lamb No. 2

Lamb No. 2 was of the best mutton conformation of any of the lambs. The face was broad, the nostrils and mouth wide, and the body deep. It quickly became adapted to the change of environment from the feed lot to the barn loft, and from the beginning ate with a ravenous appetite.

Lamb No. 3, the largest framed animal of the six, was an open fleeced individual of the type so often found in the offspring of Merino ewes when they are crossed with one of the Down breeds. This lamb was a little more leggy than either No. 1 or No. 2. Its temperament was good. Lamb No. 3 was a typical specimen of western feeder lamb.

Lamb No. 3.

Lamb No. 4

This lamb had a good temperament and quickly adapted itself to the new conditions. It was a typical western lamb and resembled lambs No. 3 and 5 in conformation.

Lamb No. 5

Lamb No. 5 was very similar in conformation to Lambs 3 and 4. It was a typical western feeder lamb. Lamb No. 5 quickly became accustomed to the new surroundings.

Lamb No. 6 was the smallest of the lot and displayed more Merino conformation than the others. The head was small and the face rather narrow. No. 6 resembled No. 1 in temperament in that it was very timid. It was not easily handled until nearly two weeks after the feeding trial started, but it made good gains, as will be shown later.

Lamb No. 6.

All of these lambs had been fed on corn and clover hay for about two weeks before their purchase for experimental purposes. The six lambs averaged a little less than 62 pounds each in weight when they arrived at the State Farm prior to the starting of the test.

Feeds. The feeds used in this experiment were corn and alfalfa hay. The corn which was used in the feeding was grown during the season of 1913 and was of an inferior quality. It was graded as No. 3, was damp and soft. All of the corn fed during the trial was secured from one load. Two-thirds of the amount secured was then shelled and afterward one-half of the shelled corn was finely ground into corn meal. By this method it will be seen that all of the corn was of the same quality. The shelling was done with a hand sheller belonging to the University, and the grinding was done by the Dairy Department. By weighing out 100 pounds of the ear corn, shelling and weighing back the cobs, it was found that the cobs constituted 27.2 per cent of the total weight of the ear corn.

The alfalfa hay which was fed, altho very bright and clean, contained a large proportion of woody stems which the lambs were unable to consume. This fact is probably explanatory of the large amount of waste hay. On the whole the alfalfa was not satisfactory.

Water and Salt. Water was supplied twice daily from iron buckets. At the beginning of the experiment it was thot best to let the animals drink just before feeding, but after a few days it became evident that watering them after the grain ration

had been consumed would have to be resorted to, as the lambs, without exception, were apparently able to forget their thirst until after the grain had been given to them. This plan of offering the water after the grain had been eaten proved very satisfactory and was accordingly followed thruout the remainder of the experiment. No record of the amount of water drunk was kept during the feeding trial. During the digestion trial an accurate record of the amount of water consumed was kept for both the morning and evening feedings. The lambs were allowed all they would drink at each feeding time.

Ordinary table salt was given each lamb about twice each week but no account as to the amount consumed was taken.

Feeding period. The feeding period covered 70 days, beginning January 22, 1914 at 8 A. M. and ending April 1 of the same year at 6 P. M. A feeding trial of this duration is unusually short and undoubtedly better results would have been obtained had the feeding period been lengthened to 90 or 100 days but this was found to be impracticable under existing conditions. In order to get a more detailed study of the results of the feeding, the 70 day period is divided up into units of two weeks duration each. The change to corn and alfalfa was made very slowly in order to prevent any ill effects which might arise due to the lambs not being accustomed to the feed.

After the first week of feeding, Lamb No. 1, receiving shelled corn as the grain ration, refused to eat its grain. It was given a large dose of Epsom salts dissolved in water, and starved for 24 hours, after which time it ate both the hay and

grain rations with apparent relish thruout the remainder of the experiment.

The rations were, as nearly as practicable, divided into two equal parts, one of which was fed at 8 A. M. and the other at 5:30 P.M. This made an intermission of about 14 hours between the evening and morning feeding and one of about 10 hours between the morning and evening feeding.

All of the lambs were started on .25 of a pound of grain per head and in addition were given about .5 of a pound of alfalfa hay but by the end of the first period of two weeks, they were consuming an average of 1 pound of grain and approximately 2 pounds of hay per head daily.

Altho it was necessary to make some changes when the digestion trial was started, an effort was made not to disturb the lambs more than was absolutely necessary and thruout the digestion trial, great care was taken not to excite them as nervousness and excitement might cause a decrease in the gains in weight.

Records. During the feeding trial records were kept of the amounts of grain and hay consumed at both the morning and evening feedings. The scale used for this work was a dial scale graduated to ounces. No account was kept of the amount of water drunk. Weights of the individual lambs were made every two weeks, just before feeding in the morning, an ordinary Fairbanks beam scale, graduated to .25 of a pound, being used for this purpose. The weighing of the lambs took place at relatively the same time at the end of each bi-weekly period.

For the digestion trial a Buffalo scale was used, which was graduated to .02 of a pound, and the weights of all feeds, as well as the weights of the lambs, and the amount of water consumed, were taken from this Buffalo scale. All of the feeds, including all forms of corn and the hay, were weighed out prior to the starting of the digestion trial and were placed in strong paper bags. These bags were then closed and tied, thus preventing any change in composition thru drying or absorption of water from affecting the data. From every fifth sack of both the grain and hay, a sample for the composite sample was taken and placed in a Mason jar. These jars, with their contents, were taken to the laboratory for a chemical analysis of the feeds. By this method, a single analysis of each of the feeds used in the experiment is representative of that feed thruout the experiment. In the data to follow, all of the weights of ear corn have been reduced to a shelled corn basis.

Careful notes regarding the physical condition and thrift of each lamb were taken during the entire feeding period and the digestion trial. After the close of the experiment photographs were made of the individual lambs used in the test.

The weight of water drunk by each lamb during the digestion trial was taken at both the morning and evening feedings during the ten day test. The time of supplying it was the same as during the feeding trial.

All refuse hay and grain was collected and weighed, the weight recorded and taken into account.

Daily weights of each lamb were taken during the digestion

trial every morning just before feeding.

For collecting the feces, bags made of canvas and lined with rubber-surfaced cloth, were attached to each lamb by means of a leather harness. An elastic strap attached to the bag at one end, and to the under side of the belly-band at the other end, prevented the bag from slipping out of place. The harness was so constructed that the bag could be easily removed to admit of the recovery of the feces.

The feces were removed from the bags just before feeding time twice daily. The weight was observed and a definite amount for the composite sample was preserved in Mason Jars as samples for analysis.

Some idea of the construction of the bag and the harness and the method observed of attaching them to the lamb may be had from the following photo.

The discussion of the data obtained in this experiment will be taken up in two parts, the first part dealing with the feeding trial and the second part with the digestion trial.

Table 1 shows the division of lots, the numbers of the lambs placed in each lot, and the rations fed.

Table 1. Lots and Rations.			
Lot	Lamb No.	Grain fed.	Roughage fed.
A	1	Shelled corn	Alfalfa Hay
	2	Shelled corn	Alfalfa Hay
B	3	Ground corn	Alfalfa Hay
	4	Ground corn	Alfalfa Hay
C	5	Whole ear corn	Alfalfa Hay
	6	Whole ear corn	Alfalfa Hay

In the following tables are given the weights of the lambs thruout the experiment, the initial and final weights, the gains made by each animal, and the average daily gains.

Table 2. Weights of Lambs.

		Lot A			Lot B		Lot C	
		Shelled corn:			Ground corn :		Ear corn	
		:			:		:	
		No.1	No.2	No.3	No.4	No.5	No.6	
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Initial Weights	Jan.21	57.00	:62.00	:65.50	:63.50	:62.00	:59.00	
	Jan 22	57.00	62.50	65.50	64.00	62.50	59.00	
	Jan.23	57.00	:62.50	:65.50	:64.00	:62.50	:59.00	
Average Initial Weights		57.00	:62.33	:65.50	:63.83	:62.33	:59.00	
Weight at end of			:	:	:	:	:	
First period-15 days		58.00	:65.00	:68.00	65.00	:66.00	:62.00	
Second period-13 days		62.00	69.00	70.00	68.00	:70.00	:65.00	
Third Period-14 days		66.00	76.00	75.00	71.00	:74.00	:70.00	
Fourth period-14 days		70.00	82.50	80.00	73.50	79.00	76.00	
Fifth period-14 days:								
	Mar. 31	74.50	86.50	83.00	76.00	84.00	81.00	
	Apr. 1	75.00	87.00	83.00	76.00	84.50	81.50	
	Apr. 2	75.50	87.50	83.00	76.00	85.00	82.00	
Average final weight		75.00	87.00	83.00	76.00	84.50	81.50	

Table 3. Gains made by each lamb during each period.

	Shelled corn			Ground corn			Ear corn		
	No. 1	No. 2	Ave.	No.3	No.4	Ave.	No.5	No.6	Ave.
	lbs.	lbs.	Lot A:	lbs.	lbs.	Lot B	lbs.	lbs.	Lot C.
1 st. period	1.0	2.67	1.83	:2.5	1.17	1.835	3.67	3.0	3.335
2 nd. period	4.0	4.0	4.00	:2.0	3.0	2.50	4.0	3.0	3.50
3 rd. period	4.0	7.0	5.50	5.0	3.0	4.00	4.0	5.0	4.50
4 th. period	4.0	6.5	5.25	5.0	2.5	3.75	5.0	6.0	5.50
5 th. period	<u>5.0</u>	<u>4.5</u>	<u>4.75</u>	<u>3.0</u>	<u>2.5</u>	<u>2.75</u>	<u>5.5</u>	<u>5.5</u>	<u>5.50</u>
Total gain	18.0	24.67	21.335	17.5	12.17	14.835	22.17	22.50	22.33

Table 4. Average Daily Gain per Lamb.

Period	Lot A			Lot B			Lot C		
	Shelled corn			Ground corn			Ear corn		
	No.1	No.2	Ave. Lot A.	No.3	No.4	Ave. Lot B.	No.5	No.6	Ave. Lot C.
1st.	.0666	.1780	.1223	.1666	.0780	.1220	.2446	.2000	.2223
2nd.	.3077	.3077	.3077	.1538	.2307	.1922	.3077	.2307	.2692
3rd.	.2857	.5000	.3928	.3571	.2142	.2856	.2857	.3571	.3214
4th.	.2857	.4642	.1880	.3571	.1785	.2678	.3571	.4285	.3928
5th.	.3571	.3214	.3392	.2142	.1785	.1963	.3928	.3928	.3928
Average for total trial	.2606	.3542	.3074	.2500	.1760	.2130	.3174	.3218	.3196

Table 2 shows that in no case did any of the lambs fail to make a gain during any bi-weekly period of the test. Lamb No. 1 gained only 1 pound but this is probably accounted for by the fact that this lamb was off feed for about three of four days during the period. After the close of the second period his gain was as good as that of most of the other lambs.

A study of Tables 3 and 4 on the total gains and average daily gains made by each lamb shows that on the whole, the gains made were rather uniform and for two of the lots, A and C, were fairly high. One of the most remarkable features of the experiment was the gains made by Lamb No. 2 getting shelled corn. As will be seen by a study of the table, this animal gained more pounds during the third period than any other lamb on test, averaging a daily gain of .5 of a pound. This one animal seemed to be superior to all of the others as a feeder

and in disposition from the very beginning of the experiment. Lamb No. 2 started the feeding trial weighing about $1\frac{1}{2}$ pounds less than No. 4 getting ground corn, but at the end of the test No. 2 weighed 11 pounds more than No. 4. Taking the averages of the lots, however, the animals receiving whole ear corn made the largest gains and hence the largest daily gains of any of the three lots. At first sight it may seem that the average daily gain of Lamb No. 1 is very low in comparison with the other gains of lambs getting unground grain, but if the gain for the first period, when Lamb No. 1 was off feed, is not considered, the average daily gain of Lamb No. 1 for the remainder of the feeding trial is .3091 of a pound, which compares very favorably with the average daily gains of the two animals receiving whole ear corn.

A study of this table shows that in this particular case the unground grain was superior, in both cases, to the ground. The ear corn seemed to be slightly superior to shelled corn, but the ground corn was decidedly the inferior feed of the three so far as daily gains are concerned.

In the following table is given the amounts of grain required to produce 100 pounds gain on each lamb during each of the five two-weeks periods.

Table 5. Grain Consumed per 100 pounds gain.

Lot A			Lot B			Lot C.		
Shelled corn			Ground corn			Ear corn		
Period	No. 1	No. 2 Ave. Lot A	No. 3	No. 4	Ave. Lot B	No. 5	No. 6	Ave. Lot C.
1st.	575.0	432.3 503.65	440.0	940.2	690.1	326.4	365.3	345.8
2nd.	325.0	325.0 325.0	650.0	433.3	541.65	304.0	405.3	354.65
3rd.	350.0	200.0 275.0	280.0	466.6	373.3	328.5	268.0	298.25
4th.	350.0	215.3 280.65	280.0	560.0	420.0	268.0	220.33	244.16
5th.	280.0	311.1 295.55	466.6	560.0	513.3	256.2	246.5	251.35
Ave.	376.0	294.74 335.37	423.32		507.67	296.6	301.08	298.84
					592.02			

On the whole the requirements of grain per 100 pounds gain are uniform thruout the whole trial except in the first period, and here we would naturally expect a larger fluctuation on account of the animals not being accustomed to the ration. According to the average requirements of grain per 100 pounds gain, whole ear corn is decidedly superior to ground corn for fattening lambs. Comparing the lots from the standpoint of economy of gain, that is grain per 100 pounds gain, it is seen that the unground grain has a still greater advantage over the ground grain, than compared on the basis of amount and rate of gain. The last table indicates, too, that at least there is no advantage to be derived from shelling corn for lambs.

Table 6 Total Pounds of Grain Consumed.

Lot A.			Lot B.			Lot C.			
Shelled corn			Ground corn			Ear corn			
Period	No.1	No.2 Ave. Lot A	No. 3	No. 4	Ave. Lot B.	No. 5	No.6	Ave. Lot C.	
1.	5.75	11.50	8.62	11.00	11.00	11.00	11.98	10.96	11.47
2.	13.00	13.00	13.0	13.0	13.0	13.0	12.16	12.16	12.16
3.	14.0	14.0	14.0	14.0	14.0	14.0	13.14	13.40	13.27
4.	14.0	14.0	14.0	14.0	14.0	14.0	13.40	13.22	13.31
5.	14.0	14.0	14.0	14.0	14.0	14.0	14.09	13.56	13.82
Total	60.75	66.50	63.62	66.00	66.00	66.00	64.77	63.30	64.03

Table 6 shows that Lot C actually consumed less grain during the experiment than did either of the other two lots altho Lot C made the best gains. It will be seen that, for an average thruout the feeding trial, Lot B, which made the poorest gains of any of the three lots, consumed more grain than the others. The small amount of feed consumed by the lambs of Lot A is partly due to the small amount of corn consumed by Lamb No. 1 during the first period when it was off feed. During all of the other periods Lots A and B consumed an equal number of pounds of grain. In giving the grain to Lot C, the ears of corn were weighed before being fed and the weight was recorded. At the end of each bi-weekly feeding period, 27.2 per cent of the total number of pounds of ear corn was subtracted from the amount fed and the remainder was taken as the amount

consumed. The reason for this was to secure the actual amount of grain eaten, exclusive of the cobs, which of course, were wasted. As previously stated, a test showed this corn to run about 27.2 per cent cobs by weight.

The amounts of hay fed, consumed, and the number of pounds of hay required to produce 100 pounds gain are presented in Tables 7, 8, and 9.

Table 7 Hay Fed.

Period.	Lot A Shelled corn			Lot B. Ground corn			Lot C. Ear corn		
	No. 1	No. 2	Ave.	No. 3	No. 4	Ave.	No. 5	No. 6	Ave.
	Lot A			Lot B			Lot C		
1	18	24	21	22	22	22	22	22	22
2	26	26	26	26	26	26	26	26	26
3	28	28	28	28	28	28	28	28	28
4	28	28	28	28	28	28	28	28	28
5	28	28	28	28	28	28	28	28	28
Totals	128	134	131	132	132	132	132	132	132

Table 8 Hay Consumed. Lbs.

Period	Lot A			Lot B			Lot C		
	Shelled corn			Ground corn			Ear corn		
	No.1	No.2	Ave.	No. 3	No. 4	Ave.	No. 5	No. 6	Ave.
1	15.4	22.2	18.8	18.6	19.2	18.9	18.8	19.0	18.9
2	22.0	24.4	23.2	22.6	24.4	23.5	23.6	24.0	23.8
3	23.4	22.8	23.1	23.0	23.0	23.0	22.2	23.0	22.6
4	24.4	23.6	24.0	24.0	24.8	24.4	23.0	22.8	22.9
5	26.8	27.4	27.1	27.05	25.62	26.33	26.8	25.7	26.2
Totals	112.0	120.4	116.2	115.25	117.02	116.13	114.4	115.5	114.9

Table 9.
Hay Required per 100 pounds Gain. Lbs.

Period	Lot A			Lot B			Lot C		
	Shelled corn			Ground corn			Ear corn		
	No. 1	No.2	Ave.	No. 3	No. 4	Ave.	No. 5	No. 6	Ave.
1	1540.0	834.6	1187.3	744.0	1641.0	1192.5	508.1	633.3	570.7
2	550.0	610.0	580.0	1130.0	813.3	971.6	590.0	800.0	695.0
3	585.0	325.7	455.3	460.0	766.6	613.3	555.0	460.0	507.5
4	610.0	363.1	486.5	480.0	992.0	736.0	460.0	380.0	420.0
5	536.0	608.8	572.4	901.6	1024.8	963.2	487.2	467.0	477.1
Ave.	764.2	544.44	654.32	743.12	1047.54	895.33	568.10	542.08	

From Tables 7 and 8 it will be observed that the amounts of hay fed and consumed by each lot were nearly identical. A total difference of only .07 of a pound lies between Lots A and B in the total amount of hay consumed and Lot C consumed only 1.3 pounds less than Lot A during the 70 days the lambs were on test.

The waste hay was removed just before each feeding and placed in a paper bag. At the end of each period, these sacks were weighed and the record taken of the amounts of waste. The waste hay has been subtracted from the pounds of hay fed to arrive at the number of pounds consumed.

Table 9 shows conclusively that in this trial a great deal more alfalfa hay was required to produce 100 pounds gain when fed with ground corn than when fed with either whole or shelled corn. This is no doubt due to the greater gains made by Lots A and C and not from the amount of hay consumed. From the Table it appears that whole corn produces a great saving of hay over shelled corn, but again it must be considered that Lamb No. 1 was not normal during the first period. Discarding the records of the first period, the average for the remainder of the trial is 570.2 pounds of hay per 100 pounds gain in weight, which is comparable with the records made by any of the other lambs receiving unground grain. The same seems to be true of Lamb. No. 4 during the first period, namely that the pounds of hay required per 100 pounds gain is excessively high, but even if we discard the figures for the first period, the amount required is practically 900 pounds, a figure far in excess of the requirements of either of the other two lots.

The average daily ration of both hay and grain consumed during the experiment is given in Table 10.

Table 10. Average Daily Ration.

Lot A							Lot B					Lot C							
Shelled corn							Ground corn					Ear corn							
Lamb No.	1		2		Average		3		4			Average		5		6		Average	
Period	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	Hay	Grain	
1	1.02	.3833	1.48	.7666	1.25	.5749	1.24	.7333	1.28	.7333	1.26	.7333	1.25	.7986	1.27	.7306	1.26	.7646	
2	1.69	1.0	1.88	1.0	1.78	1.0	1.74	1.0	1.87	1.0	1.80	1.0	1.81	.935	1.85	.935	1.83	.935	
3	1.67	1.0	1.63	1.0	1.65	1.0	1.64	1.0	1.64	1.0	1.64	1.0	1.58	.938	1.64	.957	1.61	.947	
4	1.74	1.0	1.68	1.0	1.71	1.0	1.71	1.0	1.77	1.0	1.74	1.0	1.64	.957	1.63	.944	1.63	.950	
5	<u>1.91</u>	<u>1.0</u>	<u>1.96</u>	<u>1.0</u>	<u>1.93</u>	<u>1.0</u>	<u>1.93</u>	<u>1.0</u>	<u>1.83</u>	<u>1.0</u>	<u>1.88</u>	<u>1.0</u>	<u>1.91</u>	<u>1.06</u>	<u>1.84</u>	<u>.968</u>	<u>1.87</u>	<u>1.014</u>	
Ave.	1.60	.876	1.72	.953	1.66	.914	1.65	.946	1.67	.946	1.66	.946	1.63	.9376	1.63	.9068	1.63	.9222	

The averages for the lots shows that the daily ration was practically the same, and that each lamb was consuming about 1 pound of grain and a trifle over 1.6 pounds of alfalfa hay per day. The average for the trial is brought down perceptibly by the figures for the first period when the animals were receiving less than a full ration of either grain or hay. For all of the other periods it will be noticed that each of the lambs consumed all of the grain offered, which was one pound per day for Lots A and B and approximately that for the third lot.

Tables 11, 12, and 13 were compiled from an actual analysis of the feeds fed and in these tables are presented the amounts of the various nutrients consumed thruout the feeding trial.

Table 11. Nutrients Consumed in Grain.
Lbs.

	Lot A Shelled corn			Lot B Ground corn			Lot C Ear corn		
	No.1	No.2	Ave.	No.3	No.4	Ave.	No.5	No.6	Ave.
Dry Matter	50.6700	55.4657	53.0678	54.7879	54.7879	54.7879	54.023	52.797	53.410
Crude Protein	5.2166	5.7103	5.4634	5.8120	5.8120	5.8120	5.556	5.435	5.495
N. Free Extract	41.3154	45.2260	43.2707	45.1585	45.1585	45.1585	44.049	43.050	43.549
Ether Extract	2.3163	2.5356	2.4259	1.9622	1.9622	1.9622	2.4697	2.414	2.442
Crude Fibre	1.1056	1.2103	1.1579	1.1470	1.1470	1.1470	1.1788	1.153	1.166
Ash	.7166	.7833	.7499	.7082	.7082	.7082	.763	.746	.754

Table 12. Nutrients Consumed in Hay.
Lbs.

Dry Matter	101.7350	109.3654	105.5500	104.6870	106.295	105.491	103.915	104.006	103.961
Crude Protein	17.619	18.940	18.279	18.130	18.408	18.269	17.996	18.012	18.004
N. Free Extract	44.137	47.447	45.792	45.418	46.115	45.766	45.083	45.112	45.092
Ether Extract	2.204	2.369	2.286	2.268	2.303	2.285	2.251	2.253	2.252
Crude Fiber	28.532	30.672	29.602	29.360	29.811	29.585	29.143	29.169	29.156
Ash	9.243	9.937	9.590	9.511	9.657	9.584	9.414	9.489	9.451

Table 13. Nutrients Consumed in Grain and Hay.

Dry Matter	152.405	164.831	158.618	159.4749	161.0829	160.279	157.938	156.803	157.370
Crude Protein	22.836	24.650	23.743	23.942	24.220	24.081	23.552	23.447	23.499
N. Free Extract	85.4524	92.673	89.062	90.5765	91.2735	90.924	89.132	88.162	88.647
Ether Extract	4.5203	4.9046	4.712	4.2302	4.2652	4.248	4.7207	4.667	4.694
Crude Fiber	29.6376	31.8823	30.760	30.5070	30.9580	30.732	30.322	30.322	30.322
Ash	9.9596	10.7203	10.340	10.2192	10.3652	10.292	10.177	10.235	10.206

Tables 11 and 12 show that for all lots the alfalfa hay furnished, in round numbers, two-thirds of the total dry matter consumed in the ration, while the grain furnished only one third. This is practically in the proportion in which the two feeds were given--2:1. Here again, Lot C, which made the largest gains, consumed the smallest amount of dry matter; Lot A, ranking second in gains made, consumed about 1.3 pounds more dry matter than Lot C, while Lot B, which made the least gains, consumed the largest amount of dry matter of any of the three lots. Over two-thirds of the crude protein consumed was given in the hay. It will be seen from the tables that the alfalfa furnished about 18.2 pounds of this nutrient out of a total of 23.7 pounds consumed. The differences in the percentage composition of the feeds serves to explain more clearly the variations in the amounts of nutrients consumed. In the table below is given the results of the analysis of the feeds used.

Table 14. Composition of Feeds.

Feed	Percentage Composition, Air dry Substance.						
	Water	Crude Protein	N. Free Extract	Ether Extract	Crude Fiber	Ash	Dry Matter
Alfalfa Hay	9.165	15.731	39.408	1.968	25.475	8.253	90.835
Shelled corn and whole corn	16.593	8.587	68.009	3.813	1.820	1.178	83.407
Ground corn	16.988	8.806	68.422	2.973	1.738	1.073	83.012

The analyses of these feeds are not essentially different from the percentage composition given in Henry and Morrison's "Feeds and Feeding" for the same feeds.

Table 14 shows that the alfalfa hay contained about 83 per cent more crude protein and about 72.5 per cent less nitrogen-free extract than the grain contained. It is evident, too, that the hay furnished almost 93 per cent of the total crude fiber consumed.

Table 15, given below, shows the amounts of the various nutrients necessary to produce 100 pounds gain in live weight.

Table 15.

Nutrients in Grain and Hay Required to Produce 100 Pounds Gain In Weight.

	Lot A Shelled corn			Lot B Ground corn			Lot C Ear corn		
	No.1	No.2	Ave.	No.3	No.4	Ave.	No.5	No.6	Ave.
Dry Matter	846.69	668.10	757.39	911.28	1323.60	1117.44	712.39	702.05	707.22
Crude Protein	126.86	108.73	117.79	136.81	199.01	167.91	106.23	104.97	105.60
N. Free Extract	474.73	375.65	425.19	517.58	749.98	633.78	402.03	394.72.	398.37
Ether Extract	25.11	19.88	22.50	24.17	35.05	29.61	21.29	20.90	21.09
Crude Fiber	164.40	129.23	146.81	174.33	255.20	214.76	136.76	135.75	136.25
Ash	55.33	43.45	49.39	58.39	85.17	71.78	45.90	46.03	45.96

The table shows that Lot C, receiving whole ear corn, required less of each of the nutrients for 100 pounds gain than either of the other two lots. The difference between the amounts of nutrients required by Lot C and by Lot A is very small, but Lot B required a material increase of each nutrient to produce 100 pounds gain.

The data in detail has been given, but in order to make the important points more clear, a condensation of the essential results of the entire feeding experiment is given in the following table.

Table 16. Summary of Feeding Experiment.

	Lot A Shelled corn			Lot B Ground corn			Lot C Ear corn		
	No.1	No.2	Ave.	No.3	No.4	Ave.	No.5	No.6	Ave.
Weights:									
Initial	57.00	62.33	59.66	65.50	63.83	64.66	62.33	59.00	60.66
Final	75.00	87.00	81.00	83.00	76.00	79.50	84.50	81.50	83.00
Total Gain	18.00	24.67	21.33	17.50	12.17	14.83	22.17	22.50	22.33
Av. Da. Gain.	.2606	.3542	.3074	.2500	.1760	.2130	.3174	.3218	.3196
Feeds:									
Grain consumed	60.75	66.50	63.62	66.00	66.00	66.00	64.77	63.30	64.03
Grain consumed per 100# Gain	376.00	294.74	335.37	423.32	592.02	507.67	296.6	301.08	298.84
Hay consumed	112.00	120.40	116.20	115.25	117.02	116.13	114.40	115.50	114.90
Hay consumed per 100# Gain	764.20	544.44	654.32	743.12	1047.54	895.33	516.06	568.10	542.08
Total Dry Mat- ter consumed	152.40	164.83	158.62	159.47	161.08	160.28	157.94	156.80	157.37

A summary of the feeding trial shows that the shelling of corn did not increase its feeding value for fattening lambs in this particular case when alfalfa hay was used as the roughage. The results obtained are in accordance with those of previous experiments carried on along the same line. The results of this trial tend to show that the grinding of corn not only does not increase its feeding value for lambs, but actually decreases it.

PART II.

Coefficients of Digestibility of Feeds Used in the Feeding Trial.

The relative values of ear corn, shelled corn, and ground corn for fattening lambs have been discussed. The question now arises as to whether or not the differences in the feeding values of these corn preparations are due to differences in the percentage of the grain which is digested, or to some other factor.

For the benefit of those who are unfamiliar with the terms used thruout the data to follow, the definitions of the terms are here presented. These definitions are taken from a bulletin published by the Texas Experiment Station*, and were written by Chemist Geo. S. Fraps.

Definition of Terms.

"The ordinary analysis of a feeding stuff gives its content of water, ash, protein, ether extract, crude fiber, and nitrogen-free extract, expressed in percentages.

"Protein, being the constituent of food which forms flesh, muscle, hair, ligamnets, and other portions of the animal body, is of great importance. It replaces the wear and tear of the animal body and furnishes material for additional flesh. Besides furnishing material for tissue, protein may be burhed in the body to produce heat, or it may serve as a source of fat in case of a deficiency in carbohydrates and fat accompanied by excess of protein. It is, however, a costly source of heat and

*Texas Bul. 147

fat. Protein is the most expensive portion of a food, and feeds rich in protein usually sell for a higher price than feeds low in protein, though the difference is not as great in Texas as in the northern states. With a given feed, the more protein it contains, the better its quality, compared with other feeds of the same kind.

"Ether Extract is composed mainly of fats and oils in the case of concentrated feeding stuffs, but with fodders and hays it is often composed to a considerable extent of waxes, coloring matter, and other substances. Fat is used in the animal body as a source of body fat and to furnish heat and energy. The animal requires heat to keep its body warm and energy to run the animal mechanism or do outside work. The beating of the heart, chewing, movements of the intestines, and the involuntary muscular movements require energy which is furnished by the oxidation of fats, carbohydrates, or protein. One pound of fat is equal to 2.25 pounds of carbohydrates. Fat ranks next to protein in its value in a feeding stuff. The more protein and fat a given feed contains, the better its quality compared with other feeds of the same kind.

"Crude Fiber is the portion of the plant which resists the intense action of acids and alkalis. It consists mostly of the cell walls and woody fiber of the plant, and is the most indigestible part of the feed stuff. By means of fermentation in the intestines, crude fiber is digested to some extent in animals which chew the cud. The operation, however, consumes so much energy that a large portion of the ^{value of} crude fiber is taken up by the

process of digestion. Hays and fodders and other roughage generally contain much crude fiber, but concentrated feeding stuffs comparatively small quantities of it. Crude fiber is the woody and less digestible portion of a feeding stuff. The more crude fiber a feed contains, the poorer its quality compared with other feeds of the same kind. Crude fiber contains some cellulose which is a carbohydrate.

"Nitrogen-Free Extract is composed of starch, sugar, dextrin, and other substances of similar nature. These substances are mostly carbohydrates; that is, they contain carbon and hydrogen in proportions to form water. Crude fiber is also composed largely of carbohydrates. The nitrogen-free extract of most concentrated feeding stuffs, such as corn chops, wheat bran, cottonseed meal, Kaffir corn, is composed largely of sugars and starches which are readily digested and have considerable value to the animal.

"The nitrogen-free extract of wheat skins, corn bran, cobs, rice hulls, hays and straws, and similar feeds, is composed mostly of other substances than sugar and starch, and has a lower value to animals. The nitrogen-free extract of these two kinds of feeds, therefore, can not be compared directly.

"In general we may say that the more protein, fat, and nitrogen-free extract, and the less crude fiber and ash a given feed contains, compared with other feeds of the same kind, the better the quality of the feeding stuff, and the reverse is also true.

"The same statement also holds in comparing feeding stuffs of different kinds, but not altogether; since, in comparing feeds

of different kinds, we must also consider their digestibility and the productive value of the digested material.

"Ash is the residue left when the plant is burned. It represents mostly the mineral portion of the plant and the portion which comes from the soil, although a part of the ingredients withdrawn from the soil are volatilized during combustion. Nitrogen is particularly driven out completely. Ash is valuable to the animal, inasmuch as it furnishes the material for bones, and some constituents of it, particularly phosphoric acid and sulphur, are essential constituents of the animal cell. Ash is necessarily present in feeding stuffs. An excessive amount indicates contamination with dirt, sand, or other mineral matter. Too little ash in the ration fed may give rise to disorders, especially in young animals.

"Water (moisture) is always contained in feeding stuffs, but since it is furnished for the most part in liquid form, it can not be considered as having any special nutritive value. The more water a feeding stuff contains, the less of the other nutrients it contains, and the more liable it is to be injured by heating, mold, etc. The water content of feeds varies, being larger in fresh grain.

Digestibility

"By the digestibility of a feed we mean that proportion of the different nutrients which disappears in the passage of the food thru the animal. Since we now know that a portion which disappears is changed into the gases, carbon dioxide and marsh gas, we know that all the so-called digested nutrients do not

enter into the system of the animal or become valuable to it. Further we now know that the digested nutrients of one feed do not necessarily have the same value to the animal, pound for pound, as the digested nutrients of another feed. For example, a pound of digested nitrogen-free extract from corn chops has a greater value to the animal than a pound of digested nitrogen-free extract from alfalfa hay. This has been definitely shown by the work of Kellner.

"The digestibility of a feed, and its content of digestible nutrients is nevertheless, of great significance in judging the nutritive value of a feed. The feeding value can be calculated, more or less accurately, from the digestion value.

"By coefficient of digestion we mean the percentage or the proportion which is digested. For example suppose the coefficient of digestibility of protein in green corn is given at 59.7. This means that 59.7 per cent of all the protein in the corn disappears in the passage of the feeding stuff through the animal."

$$\frac{\quad}{\quad} \frac{0}{0}$$

Experiments bearing on the subject of corn preparations for sheep and lambs have been very few. It is no doubt true that most of our digestion trials both in the United States and in the European countries have been conducted with sheep but the coefficients of digestibility of corn in various forms for these animals has not been considered of paramount importance.

A review of the American investigations bearing on the subject of the digestibility of corn preparations is here presented.

At the Massachusetts Station* Lindsey, et al. conducted an experiment with two mature sheep, one of which weighed 140 pounds and the other 137 pounds. Both sheep received a ration composed of English hay and corn meal. The author gives the compositions of the feeds used as follows:

	Protein	N.-Free Ex't.	Fat	Fiber	Ash
Corn meal	10.93%	80.15%	4.86%	2.60%	1.46%
English Hay	9.80	49.31	2.64	31.84	6.41

No data bearing on the digestibility of the corn meal in the ration are presented in the bulletin, but Lindsey and his associates found the combined ration to have the following coefficients of digestion:

Sheep No.	Dry Matter	Protein	N.-Free Extract	Fat	Fiber	Ash
I	71.34	63.34	74.97	61.58	72.45	47.40
II	70.09	63.00	74.18	58.69	70.76	47.68

The results obtained are remarkably uniform.

Bartlett, of the Maine Station** conducted a digestion trial with three wethers in an effort to determine the digestion coefficients of corn meal when fed in a ration of corn meal and clover hay. No description of the corn meal is available from the bulletin except that it was "made from ordinary western corn, rather coarsely ground." The results of the analysis of the meal are given below:

Composition of corn meal. Per cent.

Water	Ash	Crude Protein	Crude Fiber	N.-Free Extract	Fat
14.55	1.60	9.63	2.18	69.17	2.87

* Bul. 152

** Bul. 67

The author does not describe the wethers used in this experiment and no hint is given as to their age or size. Each of the animals received a ration of 400 grams of clover hay and 300 grams of the meal. The results follow:

Sheep No. I	Dry Matter	Ash	Crude Protein	Crude Fiber	N.-Free Extract	Fat
Fed in clover hay	1614.0	147.5	241.5	507.1	686.8	31.1
Fed in corn meal	1282.5	24.0	144.5	32.7	1038.2	43.1
Total Fed	2896.5	171.5	386.0	539.8	1725.0	74.2
Total feces	815.7	95.3	126.8	264.6	298.0	31.0
Total digested	2080.8	76.2	259.2	275.2	1427.0	43.2
Digested from clover hay	903.8	53.1	160.6	223.1	447.8	12.7
Digested from corn meal	1177.0	23.1	98.6	52.1	979.2	30.5
Per cent digested from corn meal	91.8	96.2	68.2	----	94.3	70.8
Sheep No. II						
Fed in clover hay	1614.0	147.5	241.5	507.1	686.8	31.1
Fed in corn meal	1282.5	24.0	144.5	32.7	1038.2	43.1
Total Fed	2896.5	171.5	386.0	539.8	1725.0	74.2
Total feces	907.8	91.0	142.3	287.5	356.4	30.6
Total digested	1988.7	80.5	243.7	252.3	1368.6	43.6
Digested from hay	882.9	50.2	153.6	203.9	444.4	8.1
Digested from meal	1105.8	30.3	90.1	48.4	924.2	35.5
Per cent digested from corn meal	86.2	----	62.4	-----	89.0	82.3
Sheep No. III						
Fed in clover hay	1614.0	147.5	241.5	507.1	686.8	31.1
Fed in corn meal	1282.5	24.0	144.5	32.7	1038.2	43.1
Total fed	2896.5	171.5	386.0	539.8	1725.0	74.2
Total feces	869.6	108.4	104.5	291.8	341.1	23.8
Total digested	2026.9	63.1	281.5	248.0	1383.9	50.4
Digested from hay	905.5	67.0	155.5	235.8	432.0	12.2
Digested from meal	1121.4	3.9	126.0	12.2	951.9	38.2
Per cent digested from corn meal	87.4	16.2	87.2	37.3	91.7	88.6
Average coefficients	88.5	56.2	72.9	----	91.7	80.6

The table shows a wide variation in the digestion coefficients for the corn meal alone when calculated from the ration of corn meal and clover hay. The widest variation in the coefficient for the dry matter is 5.6 per cent but that for the ash varies from 16.2 per cent to 126.2 per cent. A difference of 24.8 per cent between Sheep No. 2 and Sheep No. 3 will also be noted in the coefficient for the crude protein content of the corn meal. Again in the crude fiber coefficient, the figures run considerably over 100 per cent for two animals of the three used. Naturally this is evidence of error, tho it may not be avoidable, for certainly no animal can digest more than 100 per cent of any nutrient in any given feed. The data presented from the foregoing trial seem to indicate that individuality of the animals may be a very influential factor in determining the value of data secured in digestion experiments.

Bartlett, of the Maine Station* points out that digestion coefficients for nearly all feeds have been obtained from experiments with sheep. The author of the bulletin advances the argument that, "The small size of sheep and the ease with which they can be handled probably accounts for their more general use, but our experiments with them lead us to believe that, as a rule, they are much less desirable for this purpose than steers. They are nervous, restless, and more liable to lose their appetite when confined in stalls and parallel experiments with two or more animals are subject to wider variations. Out of a dozen different sheep the writer has used, only one really satisfactory animal equal to the steer has been found."

* Bulletin 110

To prove the theory that sheep are not as well suited for digestion experiments as steers, Bartlett conducted trials with each class of animals. A second object of the experiment was to find out the differences in the digestibility of corn meal when coarsely ground and when finely ground. Below is given a table showing the composition of the feeds used.

Composition of Feeds. (Per cent)						
	Dry Matter	Ash	Protein	Crude Fiber	N.-Free Extract	Ether Extract
Hay	83.90	4.24	5.00	26.98	44.26	3.42
Coarse corn meal	87.54	1.02	9.06	2.25	72.25	2.96
Fine corn meal	87.53	1.02	8.81	2.09	72.28	3.33

Descriptions of the animals used in the trials are not given, nor is the daily ration given. The results obtained with the sheep and with steers are presented in the following table. The coefficients of digestion for the corn meal have been calculated from the results obtained by feeding a ration of corn meal and hay.

Digestion Coefficients Obtained With Sheep

	Dry Matter	Ash	Protein	Crude Fiber	N.-Free Extract	Ether Extract
	93.2	-----	46.5	-----	79.1	-----
Coarse Meal	73.7	-----	45.4	-----	81.5	-----
Fine meal	89.2	31.3	63.2	56.4	88.6	-----

Digestion Coefficients Obtained with Steers

	78.4	-----	46.2	-----	90.1	-----
Coarse meal	88.7	-----	53.9	-----	90.5	-----
Fine meal	88.4	-----	47.7	-----	94.8	-----
	86.7	-----	50.6	-----	91.3	-----

In the "Description of Experiments," Bartlett says, "Both lots of animals gave higher coefficients for the fine meal than for the coarse, with quite close agreement, except on protein; and the low protein content of the ration probably accounts for that variation."

In the conclusions, the statement is made, "Of the animals used in these experiments, the steers had greater capacity for digesting coarse fodders low in protein, like timothy hay and corn fodders, than the sheep."

"The more nitrogenous rations were as well and in some cases better digested by the sheep than by the steers, and the addition of nitrogenous grains to the ration appeared to materially increase the sheep's digestive capacity."

"It is evident from a study of these results and others before published that as great differences in digestion coefficients will occur between sheep individually, as are likely to occur between sheep and steers. But if sheep are to be used to determine coefficients for bovines, great care should be taken to select strong animals that are good feeders and will eat coarse fodders readily, otherwise results which are too low are likely to be obtained."

At the Minnesota Station* Snyder fed one 250 pound grade Duroc barrow a ration of whole corn alone during a digestion trial. The composition of the corn was as follows:

Water	Ash	Ether Ex't.	Crude Protein	Crude Fiber	N.F.E.
11.73%	1.46%	3.88%	11.25%	2.28%	69.40%

The coefficients obtained are given below:

Dry Matter	Crude Protein	N.-Free Extract	Crude Fiber	Ash	Fat
89.7	89.9	93.91	48.7	---	77.6

At the South Dakota Station* Shepard and Koch conducted a digestion trial with two grade Merino wethers. The sheep received a ration of whole Minnesota No. 13 corn with Brome hay as a roughage. The corn used had the following composition:

Water	Ash	Ether Ex't.	Crude Fiber	Crude Protein	N.-Free Ex't.
13.97	1.27	4.29	1.90	8.96	69.61

The coefficients for the corn, as calculated from the ration of corn and hay were as follows:

	Crude Protein	N.-Free Extract	Crude Fiber	Ether Extract
Sheep No. I	80.80	94.20	----	87.83
Sheep No. II	<u>74.41</u>	<u>97.73</u>	<u>29.28</u>	<u>86.86</u>
Average for both sheep	77.6	95.97	29.28	87.35

The authors do not discuss the results obtained. The figures, however, do not show as wide variations as might be expected where the determinations of the coefficients are made indirectly as in this case.

In another digestion trial with sheep, Bartlett, of the Maine Station** secured fairly uniform results in determining the digestion coefficients of corn meal. Three aged wethers, ranging from 5 to 7 years in age were fed a ration of corn meal and hay of the following composition.

*Bul. 114

** Bul. in Annual Report, 1897.

Composition in Per cents.

Water	Ash	Crude Protein	Crude Fiber	N.-Free Extract	Fat.	
14.84	1.71	10.31	1.67	68.43	3.04	Corn meal
16.50	4.92	7.91	26.57	42.33	1.77	Hay

In the table below are given the coefficients obtained for the corn meal.

	Dry Matter	Ash	Crude Protein	Crude Fiber	N.-Free Extract	Fat
Sheep No. I	57.3	26.1	48.1	55.1	64.8	39.2
Sheep No. II	54.1	24.9	38.8	53.3	61.6	35.3
Sheep No. III	<u>53.7</u>	<u>32.3</u>	<u>46.3</u>	<u>49.0</u>	<u>60.6</u>	<u>44.1</u>
Averages	55.0	27.8	44.4	52.5	62.3	38.9

The influence of the addition of skim milk to the ration of grain and hay was then studied, using the same animals as in the first trial. The digestion coefficients for both the hay and skim milk had been previously determined and the milk found to have the following composition:

Water	Ash	Protein	Crude Fiber	N.-Free Extract	Fat
90.50%	.75%	3.56%	---	5.07%	.12%

A ration of 300 grams of hay, 3500 grams skim milk, and 300 grams of corn meal gave the following coefficients of digestibility for the corn meal.

	Dry Matter	Ash	Protein	Fiber	N.-Free Extract	Fat
Sheep No. 1	<u>92.3</u>	76.4	83.4	----	96.2	97.8
Sheep No. 2	91.4	20.0	78.9	----	96.1	97.6
Sheep No. 3	<u>85.1</u>	<u>52.1</u>	<u>68.3</u>	----	<u>93.5</u>	<u>98.9</u>
Average	89.6	49.5	76.9	-----	95.3	98.1

Seemingly the addition of skim milk increased the digestion coefficient of each of the nutrients.

At the North Carolina Station* Emery fed two goats on a ration consisting entirely of corn meal. The composition of the corn meal used in the experiment and the digestion coefficients obtained for the feed are presented in the following table.

	Water	Dry Matter	Ash	Protein	Ether Extract	N.-Free Extract	Crude Fiber
Composition of corn meal	12.68	87.32	1.32	8.81	4.39	71.25	1.55
Digestion coefficients obtained		86.89	---	66.89	80.47	94.22	----

At the New York (Geneva) Station** Ladd conducted a digestion trial with two mature cows. These cows were receiving thruout the trial a ration of 8 pounds of corn meal and 17 pounds of hay. The analyses of the feeds used follows:

	Per cent						
	Water	Dry Matter	Ash	Albumen- oids	Crude Fiber	N.-Free Extract	Fat
Hay	14.65	85.35	6.33	9.69	39.32	40.91	3.75
Corn meal	18.45	81.55	1.39	11.75	1.83	80.46	4.57

The analyses given above are reported, with the exception of the water content, on a dry basis. The digestion coefficients for the corn meal alone as calculated from the ration were

Dry Matter	Ash	Albumen- oids	Crude Fiber	N.-Free Extract	Fats
84.66	---	58.35	-----	87.14	91.9

As is the case in many of the trials reported previously,

* Bul. 97

** Report, 1888.

the coefficients of digestibility for the ash and crude fiber were valueless, probably because they were found to be over 100 per cent. The results obtained are considerably higher than those reported by Bartlett, of the Maine Station, for each of the nutrients.

Among the more recent investigations as to the digestibility of corn meal, is the work of Dietrich and Grindley of the Illinois Station*. This trial was conducted with two barrows "a little over a year old". Each of the animals was fed a sole ration of 7 pounds of corn meal. An analysis of the ground corn showed it to contain:

Dry Matter	Crude Protein	N.-Free Extract	Crude Fiber	Total Carbohy- drates	Crude Fat	Ash
86.38%	9.80%	70.03%	1.91%	71.94%	3.47%	1.17%

In the following table are given the digestion coefficients obtained for the corn meal:

	Dry Matter	Crude Protein	N.-Free Extract	Crude Fiber	Total Carbohy- drates	Crude Fat
Berkshire	89.1	82.1	93.9	33.6	92.3	65.5
Yorkshire	88.2	78.8	93.4	33.0	91.8	67.0

It will be seen that the results were very uniform for each of the nutrients. In a second trial with barrows of the same age, Dietrich and Grindley found the following coefficients for corn meal:

	Dry Matter	Crude Protein	Total Carbohydrates	Crude Fat
Pig A	87.1	80.5	89.8	77.9
Pig B	86.5	75.9	89.8	74.8

*Bul. 170

The authors state, "On comparing the coefficients of digestibility of the nutrients of the ground corn obtained in this second experiment with those obtained in the first with the same ration, it will be noted that the dry substance, carbohydrates, and crude protein, were somewhat less digestible in the second experiment than in the first, and the fat more digestible.

"The average of four tests in which a ration consisting of ground corn alone was fed to pigs at the rate of 1.83 pounds per day per 100 pounds live weight, gave the following coefficients of digestion

Dry Matter	Crude Protein	Total Carbohydrates	Crude Fat
87.7	79.3	90.9	71.3

"In two of these tests, the average coefficients of the nitrogen-free extract and of the crude fiber of ground corn were 93.6 and 31.8 per cent respectively."

Forbes, at the Ohio Station* conducted a very extensive trial in determining digestion coefficients of corn meal when fed to hogs. The animals used in this experiment were five 100 pound crossbred Yorkshire-ChesterWhite barrows and each animal was on test 12 days, during which time it received a sole ration of corn meal. Below is given the composition of the feed during each of the two periods the pigs were on trial:

*Bul. 271

Percentage Composition.

Water	Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash	Period
10.425	9.074	72.349	4.048	2.841	1.263	I
11.315	8.984	71.630	4.008	2.813	1.250	VII

The digestion coefficients of the corn meal are presented in the following table:

Period No.	Pig No.	Protein	N.-Free Extract	Ether Extract	Crude Fiber
I	1	92.16	92.24	65.46	76.95
	2	95.25	91.39	60.30	75.57
	3	92.22	92.01	62.00	76.87
	4	93.31	92.42	63.51	77.59
	5	92.51	92.38	62.45	76.78
	Average	93.23	92.09	62.74	76.75
VII	1	93.10	94.39	66.49	64.31
	2	93.72	93.63	61.47	59.69
	3	91.10	94.01	65.45	59.82
	4	93.74	93.72	67.68	58.76
	5	94.28	94.12	65.22	62.09
	Average	93.19	93.97	65.26	60.93
I and VII	1	92.63	93.32	65.98	70.63
	2	94.49	92.51	60.89	67.63
	3	92.01	93.01	63.73	68.35
	4	93.53	93.07	65.60	68.18
	5	93.40	93.25	63.84	69.44
	Average	93.21	93.03	64.01	68.85

The digestion coefficient for the crude fiber is almost 16 per cent higher on the average for the first period than for the seventh, yet in composition, the feed used was practically of the same composition regarding this nutrient, for both periods. The ether extract shows a difference in digestibility of 2.52 per cent in the two periods, yet the composition of corn meal shows that there was a difference of only .04 of 1 per cent in the two periods. The results are remarkably uniform thruout.

Jordan, writing for the United States Department of Agriculture* has compiled the data, bearing on the digestibility of corn meal, which had been secured up to the year 1900. His data follow:

Coefficients	Dry Matter	Ash	Protein	Fiber	N.-Free Extract	Fat
Maximum	93.3	---	78.7	----	100.0	98.1
Minimum	84.6	----	58.3	----	87.1	80.5
Average	89.4	---	67.9	----	94.6	92.1

The coefficients of digestion of corn meal by ruminants are given as follows:

No. of Animals	Dry Matter	Ash	Protein	Fiber	N.-Free Extract	Fat	Authority
3 sheep	89.6	49.5	76.9	----	95.3	98.1	Me. Rpt. 1897
2 cows	84.6	----	58.3	----	87.1	91.9	N.Y. State Report, 1888
1 goat	86.9	----	66.9	----	94.2	80.5	N.C. Bul. 97
2 goats	92.4	----	58.6	----	100.0	97.7	N.C. Bul. 97
3 sheep	93.3	61.9	78.7	----	96.5	92.5	Me. Rpt. 1897

The only data which are at present available bearing directly on the influence of the grinding of corn upon its digestibility, is the work of Patterson of the Maryland Station**. In this trial two horses were used, one of them 4 years old and weighing 850 pounds, the other 9 years old and weighing 950 pounds. The experiment lasted 5 days, during which time the horses were fed on a ration of yellow dent corn, which had been grown on the Station farm, and timothy hay. Below are given the analyses of the

* U. S. D. A. Bul. 77

** Bul. 51

feeds used:

	Composition. Per cent.					
	Water	Ash	Crude Protein	Crude Fiber	N.-Free Extract	Fat
Timothy Hay	11.41	4.57	4.45	33.20	42.99	3.38
Shelled corn	22.22	1.33	8.53	1.72	62.27	3.93
Corn meal	12.69	1.85	9.28	1.71	70.07	4.40

The digestibility of the timothy hay was first determined and afterward the coefficients of digestibility for the combined ration of timothy hay with shelled corn and timothy hay with corn meal. The results are presented in the following table.

Digestion Coefficients of Shelled Corn and Corn Meal

Feed	Horse No.	Dry Matter	Ash	Protein	Fiber	N.-Free Extract	Fat.
Shelled corn	1	78.08	32.00	75.84	---	91.57	52.54
	2	70.81	20.50	39.80	---	84.82	42.88
Average		74.44	26.25	57.82		88.19	47.71
Corn Meal	1	83.96	----	77.18	---	92.74	70.21
	2	92.82	62.66	73.95	---	98.70	75.99
Average		88.39		75.57		95.72	73.10

Commenting on the results obtained, Patterson says, "All the figures in the above tables show a decided advantage in favor of the corn meal over shelled corn. The horses had a better appetite when fed the meal and digested considerably more. Especially is this true with the older horse."

The author offers a comparison of the digestion coefficients and for corn as obtained with horses, pigs, ruminants. The table of

comparison follows:

Digestion Coefficients.

	Dry Matter	Pro- tein	Crude Fiber	N.-Free Extract	Fat
Corn meal--Horses	88.4	75.6	---	98.7	73.1
Corn meal--Ruminants	88.0	60.0	---	93.0	92.0
Shelled corn-Horses	74.4	57.8	---	88.2	47.7
Corn by pigs-Wolff (1) --	85.0	34.0	94.0	76.0	
(2) --	78.0	100.0	94.0	63.0	

Henry and Morrison, in their "Feeds and Feeding" give the digestion coefficients for the different classes of animals. Their results, given below, are averages from a compilation of the digestion coefficients obtained by State Experiment Stations and by the United States Department of Agriculture.

Digestion Coefficients of Corn and Corn Meal.

	Dry Matter	Crude Protein	Crude Fiber	N.-Free Extract	Fat
Corn meal (ruminants)	90.0	74.0	57.0	94.0	93.0
Corn meal (horses)	88.0	76.0	---	96.0	73.0
Corn meal (swine)	87.0	76.0	46.0	93.0	64.0
Corn (horses)	74.0	58.0	---	83.0	48.0
Shelled corn (swine)	87.0	75.0	44.0	92.0	64.0

The table shows that grinding corn for horses apparently increases its digestibility, while for swine shelled corn is as digestible as ground corn. Discussing the influence of preparation of feed on digestibility, Henry and Morrison state, "grinding, cracking, and rolling grain increase digestibility only in

the case of hard seeds which would other wise pass thru the digestive tract unbroken, or with animals unable to chew their food properly. Jordan states that crushing or grinding grain for horses may increase its digestibility as much as 14 per cent. In extensive trials at the Iowa Station with 60 lb. pigs, Evvard found that grinding or shelling corn did not increase the digestibility over that for ear corn. With 200 lb. pigs, grinding alone increased the digestibility .8 per cent, and both grinding and soaking 1.9 per cent."

Since the figures offered by the above authors represent a compilation of the results of all the work which has been done so far on the digestibility of corn and corn meal, a resumé of the experiments herein reviewed is unnecessary.

Digestibility of Alfalfa Hay.

At the Texas Station* G. S. Fraps conducted a trial with 3 sheep to determine the digestibility of alfalfa hay. The composition of the hay used in this trial was:

Protein	Ether Extract	Crude Fiber	N.-Free Extract	Ash	Water
16.17%	1.41%	28.34%	34.96%	8.14%	10.99%

No description as to the age of the animals used or the conditions under which the test was carried on are given in the bulletin. The coefficients obtained are presented in the following table:

*Bul. 147

Sheep No.	Crude Protein	Ether Extract	Crude Fiber	N.-Free Extract	Ash
2	73.92	2.74	75.39	69.88	55.95
3	75.46	12.74	50.80	57.37	59.86
4	71.91	.65	39.72	67.78	58.27
Average	73.8	4.9	45.4	65.0	58.0

The results are fairly uniform for the digestion coefficients of the protein and ash, but those for the other nutrients vary widely.

Headden, of the Colorado Station* carried on a similar experiment with three wethers, all of the animals used being between three and four years old. In the table below are presented the digestion coefficients obtained, together with the composition of the alfalfa hay used in the test.

Per cent.

	Water	Ash	Fat	Protein	Fiber	Extract	Dry Matter	No.
Composition	5.23	9.63	.80	13.12	41.05	30.17	94.77	
Digestion Coefficients		40.19	-111.67	63.40	44.49	55.23	49.56	3
		54.23	- 63.61	69.08	54.43	62.06	57.66	4
		42.54	- 97.26	67.59	44.36	52.77	48.89	8
Average coefficients		45.65	-90.85	66.69	47.76	56.69	52.04	

The table shows that the coefficients of digestibility of the fat in the hay are negative, indicating that more fat was found in the feces voided than was fed in the hay. With the exception of the coefficient for the crude fiber, the results are

* Bul. 93

somewhat lower in this experiment than those obtained at the Texas Station.

At the Kansas Station* Willard and Clothier conducted a digestion trial with steers receiving alfalfa hay as the sole ration. No data relative to the age of the animals used are available. In this experiment the object was to determine the differences in the digestibility of the hay when cut and cured at different stages of maturity. The analyses of the hay and the coefficients obtained are given in the tables below:

Analysis of Alfalfa Hay.

	Water	Ash	Protein	Fiber	N.-Free Extract	Fats
10% in bloom	8.77	9.54	16.88	29.38	34.01	1.42
50% in bloom	7.71	9.49	15.88	31.44	34.23	1.25
Full bloom	8.29	7.75	13.23	33.11	36.34	1.30

Coefficients of Digestibility of Alfalfa Hay

Cut at Different Stages in Growth.

	Dry Matter	Ash	Fats	Protein	Fiber	N.-Free Extract
10% in bloom	59.40	63.49	60.00	78.52	46.10	75.31
50% in bloom	58.29	56.41	30.39	75.14	50.44	71.99
Full bloom	60.03	60.90	51.65	76.70	50.63	75.24

The coefficients for each nutrient are much higher in this trial than either Fraps or Headden report. The table shows that the coefficients for the fat, altho varying greatly, are positive.

The Ontario Experiment Station** in a trial with sheep,

*Bul. 103

**Report of the Animal Husbandman in Annual Report 1898.

found the following coefficients for alfalfa hay:

	Dry Matter	Ash	Fat	Protein	Fiber	N.-Free Extract
1st. cutting	58.6	---	48.8	73.4	39.1	71.8
2nd. cutting	56.2	---	50.4	72.8	37.7	70.1
3rd. cutting	51.3	---	44.1	64.4	37.1	64.0

No statement as to the age of the sheep used or as to their number is given. The results are practically the same as those reported by the Kansas Station, except for the coefficients for crude fiber, which are somewhat lower.

At the Wyoming Station* Morton carried on a digestion trial with two high-grade Rambouillet wethers, each 3 years old. Sheep K weighed 107 pounds and Sheep KK, 121 pounds. The hay was run thru a cutter and chopped into 1.5 inch lengths.

Composition of alfalfa hay. (Second Cutting)

Per cent.

	Water	Ash	Ether Extract	Crude Fiber	Crude Protein	N.-Free Extract
First trial	5.83	10.28	1.46	29.35	17.32	35.76
Second trial	6.25	8.12	1.48	33.22	14.10	36.83
Third trial	6.70	8.87	1.69	27.36	15.88	39.50

The digestion coefficients obtained for the alfalfa hay for each of the three trials are presented in the following table:

* Bul. 69.

Coefficients of Digestibility of Alfalfa Hay.

		Sheep Dry Matter	Ash	Ether Ex't.	Crude Fiber	Crude Protein	N.-Free Extract
First trial	K	63.64	58.31	36.29	46.30	81.20	72.02
	KK	63.49	54.62	33.87	47.33	80.64	72.21
	Average	63.56	56.46	35.08	46.81	80.92	72.11
Second trial	K	60.17	55.38	47.92	40.98	78.04	72.20
	KK	59.80	54.18	45.83	40.56	77.01	72.38
	Average	59.98	54.78	46.87	40.77	77.52	72.29
Third trial	K	66.56	55.39	39.43	47.50	80.60	77.78
	KK	66.67	59.12	43.86	46.35	80.52	77.86
	Average	66.61	57.25	41.64	46.92	80.56	77.82
Average of three trials		63.39	56.17	41.20	44.84	79.67	74.08

In a second series of experiments with the same sheep, from those above results varying $\wedge$ were obtained, as will be seen from the following tables:

Composition of Alfalfa Hay. Per cent.

	Exper- iment	Water	Ash	Ether Ex't.	Crude Fiber	Crude Protein	N.-Free Extract
1st. cutting	VII	6.47	9.12	1.81	30.83	16.09	35.68
1st. "	VIII	8.00	9.81	2.06	28.73	16.81	34.59
2nd. cutting	IX	6.74	9.04	1.87	29.17	15.43	35.75
2nd. "	X	7.26	8.93	1.99	27.63	15.65	38.54

Coefficients of Digestibility of Alfalfa Hay.

	Sheep	Dry	Ash	Ether	Crude	Crude	N.-Free
		Matter		Ex't.	Fiber	Protein	Extract
<hr/>							
1st. cutting							
Exp't. VII	K	57.82	44.84	31.05	38.55	75.33	71.25
	KK	<u>59.08</u>	<u>46.57</u>	<u>34.38</u>	<u>42.59</u>	<u>74.33</u>	<u>70.90</u>
Average		58.45	45.70	32.71	40.57	74.83	71.07
Exp't. VIII	K	62.55	49.20	40.34	47.19	78.60	72.55
	KK	<u>62.11</u>	<u>42.77</u>	<u>35.38</u>	<u>49.14</u>	<u>77.06</u>	<u>72.50</u>
Average		62.33	45.98	37.86	48.16	77.83	72.52
2nd. cutting							
Exp't. IX	K	65.01	52.33	39.87	48.42	79.04	76.35
	KK	<u>67.02</u>	<u>55.16</u>	<u>47.86</u>	<u>52.64</u>	<u>78.55</u>	<u>77.07</u>
Average		66.01	53.74	43.86	50.53	78.79	76.71
Exp't. X	K	66.57	54.62	48.71	46.16	81.14	78.98
	KK	<u>66.03</u>	<u>54.41</u>	<u>49.56</u>	<u>46.07</u>	<u>79.56</u>	<u>78.40</u>
Average		66.30	54.51	49.13	46.12	80.35	78.69
Average of 1st. cutting		60.39	45.85	35.29	44.37	76.33	71.80
Average of 2nd. cutting		66.16	54.13	46.50	48.32	79.57	77.70
AVERAGE OF ALL CUTTINGS		64.50	55.35	43.32	46.23	79.63	75.53

Thruout both series of experiments it will be noticed that the results are remarkably uniform for the coefficients obtained for each nutrient. Morton says regarding the data, "Our experiments with first cutting alfalfa hay show higher digestion coefficients for the dry matter, crude protein, and nitrogen-free extract than the average found by other experiment Stations for all cuttings; in fact the last two constituents approach the maximum. The digestion coefficients for the ash, ether extract,

and crude fiber are a little low."

McConnell, of the Wyoming Station* continued the digestion work with sheep, using the same animals described in the previous experiment. McConnell's trial was made with first cutting alfalfa hay of the following composition:

Composition of Alfalfa Hay.					Per cent.
Water	Ash	Ether Extract	Crude Fiber	Crude Protein	N.-Free Extract
8.54	9.06	1.75	29.07	14.61	36.97

The following coefficients of digestibility were obtained:

Sheep No.	Dry Matter	Ash	Ether Extract	Crude Fiber	Crude Protein	N.-Free Extract
I	64.87	48.69	45.33	48.59	80.25	76.49
II	65.26	50.17	44.29	50.19	79.80	76.07
Average	65.07	49.43	44.81	49.39	80.02	76.28

McConnell says:

"The average digestion coefficients for first cutting alfalfa as found by this experiment are higher than the average digestion coefficients for this plant as heretofore found at this Station." *

At the South Dakota Station** Shepard and Koch conducted a digestion trial with six grade Merino wethers to determine the coefficients of digestibility of alfalfa hay. Both first and second cutting alfalfa hay were used in this trial. The composition of the hay fed, and the coefficients obtained are presented in the following tables:

* Bul. 78

** Bul. 114

Composition of Alfalfa Hay. Per cent.

	Water	Ash	Ether Extract	Crude Fiber	Crude Protein	N.-Free Extract
1st. cutting	7.64	9.33	1.87	29.54	15.84	35.75
2nd. cutting	6.46	8.68	1.61	31.67	14.75	36.82

Digestion Coefficients for Alfalfa Hay.

Sheep No.

1	35.43	38.63	43.80	77.69	70.69
2	37.07	34.35	41.81	77.84	73.52
3	38.03	40.34	50.29	80.16	75.05
4	28.17	32.67	40.20	73.88	69.71
5	39.90	42.07	44.56	79.80	76.55
6	31.16	36.51	42.39	77.74	65.39
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Average	34.39	37.44	43.84	77.85	71.75

The results are very similar to those obtained at the Wyoming Station, except that the coefficients for ash are considerably lower.

At the Nevada Station* Dinsmore conducted digestion trials with 6 common-grade range wethers to ascertain the differences in the digestibility of different varieties of alfalfa hay. All of the animals used in the test were three years old and only one sheep was used for testing each variety.

In the table below is presented the results of the analyses of the different kinds of alfalfa hay:

Composition of Alfalfa Hay. Per cent.

Variety	Water	Protein	Fat	Crude Fiber	N.-Free Extract	Ash
Arabian	6.41	20.38	4.39	27.06	30.45	11.31
Arizona	7.02	21.00	5.15	19.98	36.68	10.17
Ecuador	6.85	20.00	4.57	26.18	32.15	10.19
Texas	6.28	21.88	5.54	21.22	35.18	9.90
Montana	7.09	22.25	6.14	28.68	25.85	9.98
Mexico	7.13	21.63	6.04	18.48	36.70	10.02
Average	6.80	21.19	5.30	23.60	32.83	10.26

The coefficients of digestion obtained for the different varieties of hay are given below:

Per cent digested, all experiments.

	Dry Matter	Protein	Fat	Crude Fiber	N.-Free Extract	Ash
Arabian	64.93	77.73	47.08	41.81	61.44	53.20
Arizona	66.75	83.79	56.84	36.57	78.60	53.16
Ecuador	64.55	83.57	62.16	45.23	69.88	60.74
Texas	64.37	82.43	56.89	36.86	75.83	46.70
Montana	68.42	84.53	64.99	58.28	72.93	52.04
Mexico	61.90	80.68	61.42	19.35	75.85	49.05
Average	65.15	82.12	58.23	39.68	74.42	52.48

The digestion coefficients for all of the varieties tested are very comparable with those obtained by Morton and by McConnell at the Wyoming Station. The coefficient of digestibility for fat, however, runs much higher in this experiment than in similar ones at the other Stations. It will be seen from the table of compositions that the alfalfa hay used in this trial was abnormally high in percentages of fat and crude protein.

At the Utah Station* Widtsoe conducted a digestion trial with steers which were receiving alfalfa hay as the sole ration. The object of the experiment was to test the digestibility of alfalfa hay which had been cut at different periods of the growing season. The results follow:

Composition of Alfalfa Hay. Per cent.

Crop	Cutting	Dry Matter	Ash	Protein	Fat	Fiber	N.-Free Extract
1st.	1	85.81	8.20	10.39	2.32	27.49	51.60
	2	88.23	9.13	11.02	1.69	28.46	49.70
	3	82.34	8.06	12.25	2.03	33.26	44.40
2nd.	1	89.38	9.99	11.34	2.14	31.64	44.89
	2	88.87	7.96	12.25	2.26	31.90	45.63
	3	83.85	8.61	12.21	1.98	35.08	42.12
3rd.	1	83.16	9.79	12.39	2.42	26.00	49.40

Digestion Coefficients of Alfalfa Hay.

1st.	1	61.31	45.00	62.05	38.87	42.98	74.68
	2	58.61	42.54	65.39	28.11	37.72	72.94
	3	56.43	37.32	67.76	39.03	39.74	69.60
	Average	58.78	41.62	65.07	35.00	40.15	72.41
2nd.	1	59.64	50.38	66.16	37.54	44.89	71.20
	2	60.45	40.45	73.00	44.83	42.48	73.30
	3	60.87	47.04	72.28	44.38	45.73	70.72
	Average	60.32	46.16	70.48	42.25	44.36	71.74
3rd.	1	58.17	44.25	69.30	41.51	34.30	71.00
Average of all		59.64	43.94	67.99	34.04	41.12	72.36
Results of other Stations		58.00	-----	73.00	51.00	46.00	68.00

The coefficients for crude protein were found to average somewhat higher than is reported by other Stations, and the

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coefficient for fat was much lower. Widtsoe states, "The animals used were of the common native stock of this country and no selection was employed in taking them for the work. Each set had been fed on the feed tested for at least a month before the experiment began."

At the Minnesota Station* Snyder carried on a digestion trial with two steers to determine the digestion coefficients of alfalfa hay when fed alone and in combination with other feeds. The composition of the hay fed is given below:

Composition of Dry Matter in Alfalfa Hay. Per cent				
Protein (N.x 6.25)	Ether Extract	Crude Fiber	N.-Free Extract	Ash
17.42	2.62	34.11	37.03	8.37

In the following table are given the digestion coefficients obtained for the hay, and the rations used.

	Steer No.	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N.-Free Extract	Ash
Alfalfa as sole ration	181	68.60	76.59	57.84	58.23	75.48	54.89
	184	63.09	74.17	53.92	56.91	68.25	47.92
Average		65.84	75.38	55.88	57.57	71.86	51.40
Alfalfa and corn meal	181	71.80	84.62	61.46	64.60	73.64	66.98
	184	70.16	83.25	60.19	61.98	73.24	62.70
Average		70.98	83.63	60.82	63.29	73.44	64.84
Alfalfa, corn meal, and stock food	181	61.16	66.70	27.05	47.87	74.18	56.38
	184	60.24	68.48	28.33	51.27	70.66	43.28
Average		60.70	67.59	27.64	49.57	72.42	49.83
Alfalfa, barley and mangels	181	63.83	74.90	53.29	48.41	73.36	63.22
	184	63.51	77.56	56.46	49.64	70.68	61.64
Average		63.67	76.23	54.87	49.02	72.02	62.43

* Bul. 80

The addition of corn meal to the ration seems to have greatly increased the digestibility of each nutrient, while the addition of the stock food apparently decreased the digestibility to a point lower than for the alfalfa hay alone.

Jordan, compiling the results of American investigations relative to the digestibility of alfalfa hay* which had been done prior to the year 1900, gives the following coefficients:

	Dry Matter	Ash	Protein	Fiber	N.-Free Extract	Fat
Maximum	60.2	40.9	77.0	49.0	71.8	54.0
Minimum	57.0	38.0	68.8	43.3	64.0	48.4
Average	58.9	39.5	72.0	46.0	69.2	51.0

Fraps, of the Texas Station** gives a complete resumé of the data on the digestibility of alfalfa hay. His table follows:

Reference	Protein	Fat	Crude Fiber	N.-Free Extract	Ash
Minn. Bul. 99	68.81	15.75	41.31	69.05	24.41
Colo. Bul. 93	66.69	-----	47.76	56.69	45.65
Colo. Bul. 93	72.54	29.86	49.93	72.89	57.67
Wyo. Bul. 78	80.02	44.81	43.39	76.28	49.43
Wyo. Bul. 78	79.30	49.50	45.77	75.84	55.24
Wyo. Bul. 69	79.63	43.32	46.23	75.53	55.35
Wyo. Bul. 69	79.57	46.50	48.32	77.70	54.13
Wyo. Rpt. 1904-05	79.67	41.20	44.84	24.08	56.17
So. Dak. Bul. 114	77.85	37.44	43.84	71.75	34.99
Kans. Bul. 103	76.78	51.65	50.63	75.24	60.94
Kans. Bul. 103	78.52	60.00	46.10	75.31	63.49
Kans. Bul. 32	75.14	30.30	50.44	71.99	72.05
U.S.D.A. Bul. 77	68.80	48.40	43.30	71.80	-----
U.S.D.A. Bul. 77	70.30	50.60	45.70	71.80	40.90
U.S.D.A. Bul. 77	77.00	54.00	49.00	64.00	38.00
Texas Bul. 147	73.80	4.90	45.40	65.00	58.00
Average	75.27	40.57	46.37	68.43	50.08

* U. S. D. A. Bul. 77

** Bul. 147

Henry and Morrison*, in a compilation of all the work which had been done up to 1915 on the digestibility of alfalfa hay, give the average coefficients as follows:

Alfalfa Hay.	Dry Matter	Crude Protein	Fiber	N.-Free Extract	Fat
Average of all trials	60.0	71.0	43.0	72.0	38.0
First cutting	59.0	67.0	42.0	72.0	38.0
Second cutting	62.0	76.0	44.0	74.0	40.0
Third cutting	58.0	70.0	40.0	70.0	42.0
Budded to full bloom	60.0	70.0	43.0	72.0	39.0
Average	59.8	70.8	42.4	72.0	39.4

Comparing the above averages with the averages given by the same authors for corn meal and shelled corn as digested by ruminants, it will be seen that the coefficients of digestibility for each nutrient of the alfalfa hay is decidedly lower than for the same nutrient in the grain.

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* Henry and Morrison: "Feeds and Feeding." Page 649-650.

A Digestion Trial With Lambs.

Conducted by the writer.

A description of the animals used in this digestion trial has been previously given (Pages 29 to 34). The methods of collecting the feces, feeding, taking of the records, and the conditions under which the experiment was conducted have also been given.

The first digestion trial, to determine the coefficients of digestion of a combined ration of alfalfa hay and corn meal, was started at 7:30 A. M. on March 18, 1914 and continued thereafter for 10 consecutive days. The first of the excrement voided was collected at 5:30 P. M. on the first day of the experiment.

In table 17, presented below, are given the weights of the individual lambs during each day of the trial, the total gains made and the average daily gains.

Table 17. Weights and Gains. Lbs.

Date	Lamb No.1	No. 2	Lamb No. 3	No. 4	No. 5	No. 6
March	Shelled corn		Ground corn		Ear corn	
18	70.0	82.5	80.0	73.5	79.0	76.0
19	70.0	81.5	79.5	73.5	79.0	76.0
20	70.5	82.5	79.5	75.0	79.5	76.0
21	72.0	83.5	81.5	74.5	80.0	77.5
22	72.5	84.0	81.5	75.5	80.5	78.0
23	72.5	84.5	81.5	75.0	80.0	79.0
24	73.0	85.0	81.5	75.5	81.5	79.0
25	73.5	85.0	81.5	75.5	81.0	79.0
26	73.5	85.0	82.0	75.5	82.0	79.5
27	73.5	85.0	82.5	75.5	83.0	79.5
Average weight	72.10	83.85	81.10	74.90	80.55	77.95
Total gain	3.5	2.5	2.5	2.0	4.0	3.5
Av. daily gain	.35	.25	.25	.20	.40	.35

The averages given in Table 17 show that whole ear corn produced better gains, when fed with alfalfa hay, than either shelled or ground corn when fed with alfalfa hay. The difference, however, is slight. The essential point to be considered here is the fact that all of the lambs in the experiment were more than maintaining their weights during the time they were on test.

Thruout the trial, Lamb No. 1, No. 2, No. 3, and No. 4 were receiving exactly one pound of grain per day per head and two pounds of alfalfa hay. No. 5 and No. 6 received ear corn and consequently the exact weight of their grain ration was not determined until after the grain had been removed by the lambs from the cobs. The cobs were then weighed and the weight subtracted from the total weight of the ears of corn. Table 18 shows the total amounts of hay and grain given to the lambs during the experiment.

Table 18. Feeds Given. Lbs.

Lamb No.1		2		3		4		5		6	
Shelled corn				Ground corn				Ear corn			
H.*	G.**	H.	G.	H.	G.	H.	G.	H.	G.	H.	G.
20	10	20	10	20	10	20	10	20	11.48	20	11.12

Table 18 shows that Lambs No. 5 and No. 6 received 1.48 lbs. and 1.12 lbs. more grain respectively than any of the other four lambs. It was impossible to determine the weight of the corn on the ear until after the grain had been removed, hence the difference in the amounts of grain fed to No. 5 and to No. 6

* "H" stands for Hay.

** "G" stands for Grain.

The weights of the excrement voided, taken twice each day during the digestion experiment, are given in the following table:

Table 19. Weights of Feces. Lbs.

Date	Lamb											
March	No.1		2		3		4		5		6	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
18		.74		.70		.44		.32		.60		.32
19	.82	.68	1.28	.66	1.06	.36	.52	.38	.86	.46	.50	.48
20	.68	.74	.96	.76	.76	.36	.42	.56	.76	.62	.40	.44
21	.58	.84	.72	.74	.58	.58	.36	.72	.62	.66	.40	.58
22	.78	.94	.82	.92	.60	.88	.54	.74	.64	.70	.52	.56
23	.58	.86	.72	.84	.72	.70	.44	.60	.56	.66	.56	.52
24	.58	.90	.76	.84	.72	.74	.48	.46	.74	.58	.62	.54
25	.72	.90	.80	.90	.82	.72	.60	.48	.92	.76	.56	.56
26	.82	.98	1.00	.96	.82	.75	.52	.48	.72	.73	.54	.54
27	.62	.82	.88	1.00	.73	.76	.46	.62	.75	.68	.48	.56
28	.73		.92		.78		.74		.66		.48	
Total												
Voided	15.31		17.18		14.08		10.44		13.68		10.16	
Dry												
Matter												
Voided	5.778		6.440		6.144		4.492		5.732		4.177	
Average												
daily												
excrement	1.53		1.72		1.41		1.04		1.37		1.02	

Table 19 shows that the amount of feces voided by each lamb was much greater during the day than during the night. The feces voided during the night were collected the following morning and the excrement from the day period was collected in the evening. The greater amount of feces, therefore, was voided during the shorter period. The difference in the weights of the feces during these two periods must be due to the fact that during most of the night, the animals were lying down resting and did not have the intestinal activity that they had during the day time.

It is evident from the table that the weight of fresh feces voided is not an indication as to the amount of dry matter voided. Lamb No. 3 voided 1.23 pounds less feces than No. 1, yet No. 3

voided .366 of a pound more dry matter than No. 1. Lamb No. 5 voided 1.63 pounds less fresh feces than No. 1 but voided almost an equal amount of dry matter.

The table also shows that the weight of the lamb is not an indication as to the amount of excrement which will be voided. Lamb No. 4, weighing 73.5 pounds at the beginning of the experiment, voided only 10.44 pounds of dung, which Lamb No. 1, weighing 3.5 pounds less than No. 4, voided 15.31 pounds. Lamb No. 5, weighing 79 pounds at the beginning of the experiment, excreted 13.68 pounds of dung, and during the same period, on a total grain ration of approximately 1.5 pounds less than No. 5 received, No. 1, weighing 70 pounds, excreted 15.31 pounds of feces.

Table 19 shows that on the same ration of hay and grain, the amount of feces voided by each lamb varies from day to day, and does not even tend to remain constant. On March 19, Lamb No. 3 had voided 1.06 pounds of manure; 24 hours later, during an equal length of time and on an equal amount of feed, this lamb voided only .76 of a pound, a decrease of .3 of a pound or about 28.3 per cent. Other variations similar to the example given will be found for each of the lambs on experiment.

In the following table is given the amount of water drunk by each lamb during each of the ten days of the experiment, the total amount of water drunk, and the average daily amount. The maximum and the minimum temperatures during each of the days during the test, are also presented.*

* Temperatures secured from Local Office of U. S. Weather Bureau.

Table 20. Water Drunk. Lbs.

<u>Date</u> <u>Mar.</u>	Lamb No.1	2	3	4	5	6	Temperature Degrees F.	
							Max.	Min.
18	2.72	2.92	2.12	3.62	3.16	3.04	36	23
19	3.16	3.56	2.06	3.30	3.30	3.00	30	20
20	2.90	3.96	1.84	1.20	2.86	2.92	37	8
21	4.30	3.74	3.22	2.96	3.30	2.90	37	26
22	1.94	2.50	2.50	3.96	3.08	3.04	46	19
23	1.60	2.64	2.56	1.84	2.04	5.02	58.	26
24	4.72	5.38	3.78	4.20	5.34	3.72	68	40
25	5.76	6.22	5.34	2.20	4.94	3.38	70	50
26	4.62	4.65	4.41	3.10	4.56	3.58	73	56
27	3.12	2.74	3.18	3.28	5.18	3.80	61	49
Total	34.84	38.31	31.01	29.66	37.76	34.40		
Average daily	3.48	3.83	3.10	2.97	3.78	3.44		

Table 20 shows that the amount of water drunk by each lamb varies greatly from day to day. In general, thruout the trial, it seems that an increase in the amount of water drunk by one lamb is accompanied by an increase in the amount drunk by all of the other lambs.

From the table it appears that the temperatures during the day and night greatly influence the amount of water drunk by lambs in closed quarters. On the 24th, 25th, and 26th, the three warmest days of the trial, there was a decided increase in the consumption of water by each lamb and especially by Numbers 1 and 2. These lambs had never been shorn; consequently they were affected by the warm weather. The increased respiration, due to the higher temperature, would cause a corresponding increase in the amount of water lost thru the lungs and thus explain the greater craving for water.

At the Cornell Station*, Roberts carried on a feeding experiment with lambs to compare the values of various combinations

*Bul.. 8

of feed for fattening. The amount of water drunk per head per day was ascertained. The following table gives the data which were secured in this trial:

Lot	Ration	Gain per Lot Lbs.	Water drunk per head per day.
III	Corn 238 lbs. Timothy hay 228 lbs. Mangels 125 lbs. Turnips 97 lbs.	24.38	1.03
IV	Wheat Bran 233 lbs. Cottonseed meal 106 lbs. Clover hay 312 lbs. Mangels 151 lbs. Turnips 49 lbs.	38.66	3.95
V	Wheat bran 62 lbs. Cottonseed meal 62 lbs. Corn 204 lbs. Timothy hay 255 lbs. Mangels 143 lbs. Turnips 99 lbs.	37.56	2.45
VI	Wheat bran 62 lbs. Cottonseed meal 62 lbs. Corn 198 lbs. Timothy hay 234 lbs.	28.84	2.82

In discussing the results of the trial, Roberts says, "The amount of water drunk is a pretty certain indication of the rate of gain." From the results this appears to be true. However in the first ration, the roots, which contain a large amount of water, make up half of the ration by weight. The proportion of roots to dry feed is approximately 1 : 2, whereas in the second ration the proportion of roots to dry feed is about 1 : 3.25. This would naturally cause an increase in the water consumption in the second ration. In the third ration the proportion rises to 1 : 2.4 and there is a corresponding decrease in the amount of water drunk. Taking the analyses of the feeds fed in the

various rations from Henry and Morrison's "Feeds and Feeding", the lots are shown to have consumed the following amounts of dry matter:

Lot III	435.52 lbs.
IV	597.64
V	543.68
VI	496.91

Comparing these figures with the amount of water drunk per head per day by each lot, it will be seen that the amount drunk is apparently directly proportional to the amount of dry matter consumed, as are also the gains made.

A comparison of Table 20 with Table 17 shows that Lamb No. 2, which drank 38.3 pounds of water during the trial, gained 2.5 pounds in weight and during the same period Lamb No. 1, which drank nearly 4 pounds less water than No. 2, gained 3.5 pounds in weight. Also Lamb No. 5 gained 4 pounds on less water than No. 2 required to gain 2.5 pounds.

For this trial, at least, it seems that the amount of water drunk is no indication of the rate of gain. Comparing Table 20 with Table 26, it will be seen that in this trial the total amount of dry matter consumed did not influence the amount of water drunk. Lamb No. 5, ranking fifth in the total amount of dry matter consumed, ranked second in the total amount of water drunk, and Lamb No. 3, ranking second in the amount of water drunk, ranked fifth in the amount of dry matter consumed.

In the following table is given the weight in pounds of the waste hay from the floor of each pen during the trial. This waste was collected and weighed once daily, just before the morning feeding.

An analysis of the waste hay, other than for the water

content, was not made. In calculating the total amount of hay consumed, therefore, the waste hay from these two sources (the floors and the feed racks) has been taken as having the same composition as the hay fed, with the exception of the water content. The waste hay has been placed on an air dry basis again before being subtracted from the total hay fed. Analyses of the waste hay both from the floors and from the feed racks should have been made, as it is probable that the waste hay was lower in crude protein and higher in crude fiber than the hay fed. It was assumed that the waste hay from the floor of each pen and the waste hay from each feed rack would contain approximately the same amount of moisture, hence only one moisture determination was made.

Table 21. Waste Hay from floors. Lbs.

Date	Lamb No.1	2	3	4	5	6
March						
19	1.22	1.02	.74	.92	1.20	1.00
20	1.16	.88	1.18	.98	1.18	1.06
21	.90	.52	.78	.78	1.22	.72
22	1.28	.92	1.00	1.22	1.22	1.00
23	.94	.86	.68	.74	.96	.92
24	.54	.60	.74	.62	.88	.72
25	.84	.56	.80	.82	.96	.74
26	.52	.60	.80	.62	.62	.58
27	.66	.84	.32	.38	.88	.90
28	.66	.74	.72	1.00	1.12	.70
Total waste	8.72	7.44	7.76	8.08	10.24	8.34
Average daily waste	.872	.744	.776	.808	1.024	.834

Table 21 shows that the amount of hay wasted on the floors of the pens varied greatly among the lambs themselves and also from day to day.

There was a small amount of hay left in the feed boxes which

the lambs refused to consume. This was collected and weighed at the end of the experiment. Table 22 shows the weights of the waste hay left in the feed racks by each lamb.

Table 22. Waste Hay from Feed Racks. Lbs.

Lamb No.	1	2	3	4	5	6
	1.20	.60	.95	2.38	1.20	2.30

Table 23 shows the total amount of each feed consumed after deducting the wastes from the floors and from the racks.

Table 23. Total Feed Consumed. Lbs.*

Lamb No.	1	2	3	4	5	6
Waste hay from floors	8.72	7.44	7.76	8.08	10.24	8.34
% water in waste hay from floors, fresh to dry	22.64	22.64	22.64	22.64	22.64	22.64
% water in waste hay from floors, air dry to dry	<i>assumed</i> 9.165	9.165	9.165	9.165	9.165	9.165
Total waste hay from floors, air dry	7.426	6.336	6.608	6.881	8.721	7.102
Waste hay from racks	1.20	.60	.95	2.38	1.20	2.30
% water in waste hay from racks, fresh to dry	10.07	10.07	10.07	10.07	10.07	10.07
Total waste hay from racks, air dry	1.187	.594	.941	2.356	1.187	2.277
Waste hay from floors and racks, air dry	8.613	6.930	7.549	9.237	9.908	9.379
Hay fed	20.0	20.0	20.0	20.0	20.0	20.0
Total hay consumed air dry	11.387	13.070	12.451	10.763	10.092	10.621
Total grain consumed (No waste)	10.0	10.0	10.0	10.0	11.48	11.12

Table 24.
Composition of Feeds Given. Per cent.

	Water	Nitro- gen	Crude Protein (N.x6.25)	N.-Free Extract	Ether Ex't.	Crude Fiber	Ash
Alfalfa Hay	9.165	2.517	15.731	39.408	1.968	25.475	8.253
Shelled corn and Whole corn	16.593	1.374	8.587	68.009	3.813	1.820	1.178
Ground corn	16.988	1.409	8.808	68.422	2.973	1.738	1.073

Table 25
Total Nutrients in Grain consumed. Lbs.

	Lamb No. 1	2	3	4	5	6
Water	1.659	1.659	1.699	1.699	1.905	1.845
Dry Matter	8.341	8.341	8.301	8.301	9.575	9.275
Crude Protein	.859	.859	.881	.881	.986	.955
N.-Free Ex't.	6.801	6.801	6.842	6.842	7.807	7.563
Ether Extract	.381	.381	.297	.297	.438	.424
Crude Fiber	.182	.182	.174	.174	.209	.202
Ash	.118	.118	.107	.107	.135	.131

Table 26.
Total Nutrients in Hay Consumed. Lbs.

	Lamb No. 1	2	3	4	5	6
Water	1.044	1.198	1.141	.986	.925	.973
Dry Matter	10.343	11.872	11.310	9.775	9.167	9.648
Crude Protein	1.791	2.056	1.958	1.693	1.587	1.671
N.-Free Ex't.	4.487	5.151	4.907	4.241	3.978	4.186
Ether Extract	.224	.257	.245	.212	.199	.209
Crude Fiber	2.901	3.330	3.172	2.741	2.570	2.706
Ash	.940	1.078	1.028	.888	.833	.876

Table 27
Total Nutrients Consumed in Both Hay and Grain. Lbs.

	Lamb No.1	2	3	4	5	6
Dry Matter	18.684	20.213	19.611	18.076	18.742	18.923
Crude Protein	2.650	2.915	2.839	2.574	2.573	2.626
N.-Free Ex't.	11.288	11.952	11.749	11.083	11.785	11.749
Ether Extract	.605	.638	.542	.509	.637	.633
Crude Fiber	3.083	3.512	3.346	2.915	2.779	2.908
Ash	1.058	1.196	1.135	.995	.968	1.007

Table 28.
Percentage Composition of Feces.

Lamb No.	Water	Nitrogen	Crude Protein (N.x 6.25)	N.-Free Extract	Ether Ex't	Crude Fiber	Ash
1	59.60* 6.588**	2.076#	12.975	28.531	3.510	40.323	8.073
2	59.80 6.763	1.868	11.675	29.423	2.518	41.463	8.158
3	53.40 6.363	2.003	12.519	29.518	3.610	39.688	8.303
4	54.00 6.460	2.101	13.131	31.194	2.905	37.130	9.180
5	55.80 5.208	1.972	12.325	32.059	2.760	40.050	7.598
6	56.20 6.138	2.560	16.000	32.381	3.980	31.958	9.543

*Fresh to Airdry

** Airdry to Dry

Airdry sample.

Table 29
Nutrients Voided in Excrement. Lbs.

Lamb No.	1	2	3	4	5	6
Fresh dung voided	15.31	17.18	14.08	10.44	13.68	10.16
Dung voided, air dry pounds	6.185 ✓	6.906	6.561	4.802	6.047	4.450
Nutrients in dung (air dry)						
Water	.407	.467	.417	.310	.315	.273
Dry matter	5.778	6.440	6.144	4.492	5.732	4.177
Crude Protein	.803	.806	.821	.631	.745	.712
N.-Free Ex't	1.765	2.032	1.937	1.498	1.939	1.442
Ether Extract	.217	.174	.237	.139	.167	.176
Crude Fiber	2.494	2.864	2.604	1.783	2.422	1.422
Ash	.499	.564	.545	.441	.459	.425

Passes?
 If the total amount of a nutrient voided is subtracted from the total amount of the same nutrient consumed, the remainder will represent the total amount of the nutrient which remained in the animal's body, or in other words, the amount digested. By dividing the amount of each nutrient digested by the total amount of that nutrient consumed, the quotient, expressed in per cent, is the coefficient of digestibility for the nutrient.

In the next table is presented the total nutrients consumed, total voided, pounds of each nutrient digested, and the coefficients of digestibility obtained for each of the nutrients in the combined hay-and-grain ration.

Table 30
Digestion Coefficients Obtained for Ration of Grain and Hay.

	Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
Nutrients						
Consumed*	18.684	2.650	11.288	.605	3.083	1.058
(1) Voided	5.778	.803	1.765	.217	2.494	.499
Digested	12.906	1.847	9.523	.388	.589	.559
% Digested	69.07	69.70	84.36	64.13	19.10	52.84
Nutrients						
Consumed	20.213	2.915	11.952	.638	3.512	1.196
(2) Voided	6.440	.806	2.032	.174	2.864	.564
Digested	13.773	2.109	9.920	.464	.648	.632
% Digested	68.14	72.35	83.00	72.73	18.45	52.84
Nutrients						
Consumed	19.611	2.839	11.749	.542	3.346	1.135
(3) Voided	6.144	.821	1.937	.237	2.604	.545
Digested	13.467	2.018	9.812	.305	.742	.590
% Digested	68.69	71.08	83.51	56.27	22.17	51.98
Nutrients						
Consumed	18.076	2.574	11.083	.509	2.915	.995
(4) Voided	4.492	.631	1.498	.139	1.783	.441
Digested	13.584	1.943	9.585	.370	1.132	.554
% Digested	75.15	75.48	86.48	72.69	38.83	55.67
Nutrients						
Consumed	18.742	2.573	11.785	.637	2.779	.968
(5) Voided	5.732	.745	1.939	.167	2.422	.459
Digested	13.010	1.828	9.846	.470	.357	.509
% Digested	69.42	71.04	83.54	73.79	12.84	52.68
Nutrients						
Consumed	18.923	2.626	11.749	.633	2.908	1.007
(6) Voided	4.177	.712	1.442	.176	1.422	.425
Digested	14.746	1.914	10.307	.457	1.486	.582
% Digested	77.92	72.88	88.57	72.19	51.10	57.89

Table 30 shows that a considerable variation between the coefficients of digestibility for each nutrient exists. Especially is this true in the cases of ether extract and crude fiber. Since the grain fed to the lambs was in three different forms, the average coefficients for each of these preparations will make

* Lhs. except where otherwise indicated.

possible a more critical study of the differences in the digestion coefficients.

Table 31
Average Digestion Coefficients of the Rations Fed.

Lamb No.	Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
1	69.07	69.70	84.36	64.13	19.10	52.84
2	68.14	72.35	83.00	72.73	18.45	52.84
Average	68.60	71.02	83.68	68.43	18.77	52.84
3	68.69	71.08	83.51	56.27	22.17	51.98
4	75.15	75.48	86.48	72.69	38.83	55.67
Average	71.92	73.28	84.99	64.46	30.50	53.82
5	69.42	71.04	83.54	73.79	12.84	52.68
6	77.92	72.88	88.57	72.19	51.10	57.89
Average	73.67	71.96	86.05	72.99	31.97	55.28

From Table 31 it will be noticed that the coefficients of digestibility for the nutrients vary considerably. For each of the nutrients except crude protein, the ration containing ear corn, which was fed to No's. 5 and 6, is higher on the average than for the other two lots. With the exception of the coefficient for the ether extract, the digestion coefficients for the ration containing ground corn are higher than those for the ration containing shelled corn. The differences, however, seem to be almost as great among individuals as among lots.

In order to arrive at the digestion coefficients for the corn preparations, it was necessary to find the coefficients of digestibility of the alfalfa hay which was fed in the ration. Accordingly a second digestion trial was carried on with the same lambs used in the foregoing trial, and under the same conditions,

as described for the previous trial, except that in this second trial, the ration fed consisted solely of alfalfa hay. Three pounds of hay per day were given to each lamb, 1.5 pounds at each feeding. Grain feeding was stopped entirely on April 1, 1914 and from that time the lambs were fed on alfalfa hay for four weeks prior to the starting of the second digestion trial. This was done in order to accustom the lambs to the change from a high plane of nutrition to a low one. A few days before starting the second trial, the bags and harness used for collecting the feces were again attached. On April 30, at 7:30 A. M., the digestion trial was started and continued thereafter for ten consecutive days.

Table 32 gives the daily weights of the lambs thruout the experiment.

		Table 32. Weights. Lbs.					
Date	Lamb No.	1	2	3	4	5	6
Apr. 29		81.5	85.5	90.0	82.5	88.0	83.5
	30	81.5	85.5	90.0	82.5	88.0	83.5
May	1	81.5	85.5	90.0	82.5	88.0	83.5
	2	81.5	85.5	89.5	82.0	88.0	84.0
	3	81.5	85.5	89.5	82.5	87.5	83.5
	4	82.0	85.0	89.5	82.0	88.0	84.0
	5	81.5	85.5	90.0	82.5	88.0	84.0
	6	82.0	85.5	90.0	82.5	88.0	84.0
	7	81.5	85.5	90.0	82.5	88.0	83.5
	8	81.5	85.5	89.5	82.5	87.5	83.0
	9	81.5	85.5	89.5	82.0	87.5	83.0
	10	81.0	85.5	90.0	82.0	87.5	83.0

Table 32 shows that none of the lambs gained in weight while on a ration of alfalfa hay, but that they were able to maintain their weights. No doubt this failure to make gains was due to the reduction from a grain-and-hay ration to one of hay alone, for it is to be expected that lambs on alfalfa hay alone will make fair gains in live weight.

Table 33 shows the amount of feces voided by each lamb.

Table 33. Feces Voided. Lbs.

Date	Lamb No.	1		2		3		4		5		6	
		A. M.:	P. M.:	A. M.:	P. M.:	A. M.:	P. M.:	A. M.:	P. M.:	A. M.:	P. M.:	A. M.:	P. M.:
Apr. 30			1.06		1.00		.82		.95		1.16		.74
May	1	1.06	1.12	.94	.96	1.02	.75	1.08	.80	1.20	.86	.60	.70
	2	1.40	1.10	1.02	1.12	1.06	.82	1.00	.78	1.42	.98	.84	.85
	3	1.08	.94	1.02	.82	.98	.75	1.12	.62	1.04	.88	.85	.56
	4	1.31	1.12	1.08	1.00	1.00	.86	1.04	.82	1.50	1.16	.94	.74
	5	1.10	1.30	1.08	1.20	1.06	.96	.88	.78	1.10	1.14	.82	.96
	6	1.10	1.30	1.28	1.00	.98	.88	.84	.96	1.06	1.25	.92	.86
	7	1.12	1.14	.98	1.04	1.02	.76	.76	.64	1.32	1.08	.86	.74
	8	1.06	1.26	1.14	1.26	1.24	1.04	.86	.88	1.28	1.30	.88	.68
	9	1.08	1.06	1.22	1.26	1.06	.80	.86	.78	.96	1.02	.56	.76
	10	1.04		1.14		.96		.84		1.20		.62	
Totals		11.35	11.40	10.90	10.66	10.38	8.44	9.28	8.01	12.08	10.83	7.89	7.59
Grand totals		22.75		21.56		18.82		17.29		22.91		15.38	

Table 33 shows that during the second trial the amount of feces voided by each lamb varied greatly from day to day, even tho each animal was receiving the same daily ration. The difference in the amount voided during the day and that voided during the night is not great, but in general the amount excreted during the night is the larger. This is probably due to the four hours difference in the time between feedings.

The total amount of manure voided is much larger in this second trial than in the first. This is probably caused by the bulkier ration which the lambs were consuming. More hay was consumed in this trial than in the first on account of the absence of a grain supplement.

Table 34. Hay Consumed. Lbs.

	Lamb No.1	2	3	4	5	6
Hay Fed	30.0	30.0	30.0	30.0	30.0	30.0
Wasted on floor	11.91	12.46	9.11	12.70	13.63	14.84
% water in waste hay from floor, fresh to dry	21.40	21.40	21.40	21.40	21.40	21.40
% water in hay, air dry to dry	9.260	9.260	9.260	9.260	9.260	9.260
Wasted on floor, air dry lbs.	10.316	10.973	7.891	11.000	11.806	12.854
Wasted in racks	.46	.46	.70	.86	.38	1.58
% water in waste hay from racks, fresh to dry	X 10.07	10.07	10.07	10.07	10.07	10.07
Wasted in racks, air dry lbs.	.455	.455	.693	.852	.371	1.565
Total waste (A.D.)	10.771	11.248	8.584	11.852	12.172	14.419
Hay consumed (A.D.)	19.229	18.752	21.416	18.148	17.828	15.581

A comparison of Tables 34 and 23 shows that, on an average, about 7 or 8 pounds more hay per lamb were consumed in this digestion trial with alfalfa hay than were consumed in the trial with grain and hay.

In this trial, too, the total amount of feed consumed does not seem to influence the total amount of feces voided. A comparison of Table 34 with the preceeding table shows that Lamb No. 4 consumed 18.148 pounds of alfalfa hay and voided 17.29 pounds of excrement, whereas Lamb No. 2, on practically an equal amount of the same feed (18.752 lbs.) voided 21.56 pounds of excrement. Another example is the case of Lamb No. 6, which ate 15.58 pounds of hay and dropped 15.38 pounds of dung, while Lamb No. 5 ate

17.828 pounds of hay and dropped 22.91 pounds of dung.

Table 35. Percentage Composition of Alfalfa Hay.

Water	Nitrogen	Crude Protein (N.x 6.25)	N.-Free Extract	Ether Extract	Crude Fiber	Ash
9.260	1.910	11.937	35.240	1.600	35.860	6.103

Table 36. Nutrients in Hay Consumed. Lbs.

	Lamb No. 1	2	3	4	5	6
Hay consumed, lbs.	19.229	18.752	21.416	18.148	17.828	15.581
Water	1.780	1.736	1.983	1.681	1.651	1.443
Dry Matter	17.449	17.016	19.433	16.467	16.177	14.138
Crude Protein	2.295	2.239	2.556	2.116	2.128	1.860
N.-Free Ex't.	6.776	6.608	7.547	6.395	6.283	5.491
Ether Extract	.308	.300	.343	.290	.285	.249
Crude Fiber	6.896	6.725	7.680	6.508	6.393	5.587
Ash	1.174	1.144	1.307	1.108	1.088	.951

Table 37. Percentage Composition of Feces.

Lamb No.	Water	Nitrogen.	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash.
1	60.60* 9.82** 60.34	1.624	10.150	27.592	2.27	40.58	9.588
2	9.82 51.20	1.628	10.175	26.920	3.15	40.11	9.825
3	8.69 58.00	1.650	10.312	27.653	3.36	40.43	9.555
4	9.27 57.40	1.661	10.381	27.556	3.20	39.71	9.883
5	9.60 52.75	1.570	9.812	25.218	2.90	42.80	9.670
6	8.99	1.834	11.463	28.804	3.74	36.57	10.433

* Fresh to air dry.

** Air dry to dry.

Table 38. Nutrients Voided in Feces. Lbs.

Lamb No.	1	2	3	4	5	6
Weight of feces, fresh	22.75	21.56	18.82	17.29	22.91	15.38
% water in feces, fresh to air dry	60.60	60.34	51.20	58.00	57.40	52.75
Weight of feces, air dry	8.964	8.551	9.184	7.262	9.760	6.967
Nutrients voided:						
Water	.880	.840	.798	.673	.937	.626
Dry Matter	8.804	7.713	8.386	6.589	8.823	6.341
Crude Protein	.910	.870	.947	.754	.958	.799
N.-Free Ex't.	2.743	2.304	2.540	2.001	2.461	2.006
Ether Extract	.204	.269	.308	.232	.283	.261
Crude Fiber	3.638	3.430	3.713	2.884	4.177	2.548
Ash	.859	.840	.878	.718	.944	.727

The coefficients of digestibility for the nutrients of the hay are arrived at in the same manner as that described for the ration of grain and hay. In the following table are presented the coefficients found for each nutrient, and the total amounts of the nutrients consumed and voided.

Table 39

Coefficients of Digestibility of Alfalfa Hay.

Lamb No.	Nutrients*	Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
1	Consumed	17.449	2.295	6.776	.308	6.896	1.174
	Voided	8.084	.910	2.743	.204	3.638	.859
	Digested	9.365	1.385	4.033	.104	3.258	.315
	% Digested	53.671	60.740	59.518	33.766	47.245	26.831
2	Consumed	17.016	2.239	6.608	.300	6.725	1.144
	Voided	7.713	.870	2.304	.269	3.430	.840
	Digested	9.303	1.369	4.304	.031	3.295	.304
	% Digested	54.672	61.143	65.118	10.333	48.936	26.573
3	Consumed	19.433	2.556	7.547	.343	7.680	1.307
	Voided	8.386	.947	2.540	.308	3.713	.878
	Digested	11.047	1.609	5.007	.035	3.967	.429
	% Digested	56.846	62.949	66.344	10.204	51.653	32.823
4	Consumed	16.467	2.116	6.395	.290	6.508	1.108
	Voided	6.589	.754	2.001	.232	2.884	.718
	Digested	9.878	1.362	4.394	.058	3.624	.390
	% Digested	59.986	64.366	68.866	20.00	55.685	35.198
5	Consumed	16.177	2.128	6.283	.285	6.393	1.088
	Voided	8.823	.958	2.461	.283	4.177	.944
	Digested	7.354	1.170	3.822	.002	2.216	.144
	% Digested	45.402	54.981	60.830	.70	34.662	13.235
6	Consumed	14.138	1.860	5.491	.249	5.587	.951
	Voided	6.341	.799	2.006	.261	2.548	.727
	Digested	7.797	1.061	3.485	-.012	3.039	.224
	% Digested	55.149	57.043	63.471	----- (-4.82)	54.394	23.553

* Lbs. except where otherwise indicated.

Table 39 shows that the coefficients of digestibility for each nutrient, excepting those for ether extract, run fairly constant. Lambs No. 3 and 4 seem to have given higher coefficients for every nutrient in the hay than any of the other four lambs. An explanation of this fact is impossible to give. Lamb No. 6 voided more ether extract than was consumed in the feed and hence gave a negative coefficient for that nutrient.

An average of the coefficients obtained from each animal gives the following figures:

Average Digestion Coefficients of Alfalfa Hay.

Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
54.287	60.203	64.069	15.00	48.762	26.368

In order to arrive at the digestion coefficients for the grain, it is first necessary to calculate what part of the hay in the hay-and-grain ration was digested. In other words, it is necessary to find out how much of the total nutrients digested in the first trial were digested from the hay in the ration. This is done by multiplying the amount of each nutrient consumed in the hay of the hay-and-grain ration by the coefficient of digestion for that particular nutrient, as found out in the trial with hay alone. Having ascertained this, if the amount is subtracted from the total pounds of the corresponding nutrient digested in the hay-and-grain ration, the remainder will represent that portion of the total nutrient which was digested from the grain in the ration. Then if we divide this remainder by the total amount of the nutrient consumed in the grain of the hay-and-grain ration, the quotient, expressed in per cent, will represent the coefficient of digestibility for that nutrient in the grain.

In the following table the calculation of the steps mentioned above is accomplished by way of further elucidation.

Table 40.
Digestion Coefficients of Corn Preparations.

Lamb No.	Hay-and-Grain Ration	Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
1	Nutrients consumed in hay, lbs.	10.343	1.791	4.487	.224	2.901	.940
	Coefficients*of nutrients in hay	53.671	60.740	59.518	33.766	47.245	26.831
	Digested from hay, lbs.	5.551	1.088	2.761	.0756	1.370	.252
	Total nutrients digested, lbs.	12.906	1.847	9.523	.338	.589	.559
	Digested from grain, lbs.	7.355	.759	6.852	.3124	-.781	.307
	Per cent digested from grain	88.18	94.52	100.74	81.99	-429.12	260.16
2	Nutrients consumed in hay, lbs.	11.872	2.056	5.151	.257	3.330	1.078
	Coefficients*of nutrients in hay	54.672	61.143	65.118	10.333	48.936	26.573
	Digested from hay, lbs.	6.491	1.257	3.354	.0266	1.630	.286
	Total nutrients digested, lbs.	13.773	2.109	9.920	.464	.648	.632
	Digested from grain, lbs.	7.282	.852	6.566	.4374	-.982	.346
	Per cent digested from grain	87.30	99.18	96.54	114.80	-539.56	293.22
3	Nutrients consumed in hay, lbs.	11.310	1.958	4.907	.245	3.172	1.028
	Coefficients*of nutrients in hay	56.846	62.949	66.344	10.204	51.653	32.823
	Digested from hay, lbs.	6.429	1.233	3.256	.0250	1.638	.337
	Total nutrients digested, lbs.	13.467	2.018	9.812	.305	.742	.590
	Digested from grain, lbs.	7.038	.785	6.556	.2800	-.896	.253
	Per cent digested from grain	84.78	89.10	95.83	94.28	-514.94	236.45
4	Nutrients consumed in hay, lbs.	9.775	1.693	4.241	.212	2.741	.888
	Coefficients*of nutrients in hay	59.986	64.366	68.866	20.00	55.685	35.198
	Digested from hay, lbs.	5.864	1.090	2.921	.0424	1.526	.314
	Total nutrients digested, lbs.	13.584	1.943	9.585	.370	1.132	.554
	Digested from grain, lbs.	7.720	.853	6.664	.2276	-.394	.240
	Per cent digested from grain	93.00	94.55	97.40	76.63	-188.51	224.30
5	Nutrients consumed in hay, lbs.	9.167	1.587	3.978	.199	2.570	.833
	Coefficients*of nutrients in hay	45.402	54.981	60.830	.70	34.662	13.235
	Digested from hay, lbs.	4.162	.872	2.420	.0014	.891	.110
	Total nutrients digested, lbs.	13.010	1.828	9.846	.470	.357	.509
	Digested from grain, lbs.	8.848	.956	7.426	.4686	-.534	.399
	Per cent digested from grain	92.41	96.04	98.18	106.98	-255.50	295.55
6	Nutrients consumed in hay, lbs.	9.648	1.671	4.186	.209	2.706	.876
	Coefficients*of nutrients in hay	55.149	57.043	63.471	-----	54.394	23.553
	Digested from hay, lbs.	5.321	.953	2.657	-----	1.472	.206
	Total nutrients digested, lbs.	14.746	1.914	10.307	-----	1.486	.582
	Digested from grain, lbs.	9.425	.961	7.650	-----	.014	.376
	Per cent digested from grain,	101.62	100.63	101.15	-----	6.93	287.02

* See Table 39.

To permit of a better study of the coefficients obtained for the various corn preparations, they have been condensed in the following table.

Table 41.

Coefficients of digestibility of Corn Preparations.

Corn	Lamb No.	Dry Matter	Crude Protein	N.-Free Extract	Ether Extract	Crude Fiber	Ash
Shelled	1	88.18	94.52	100.74	81.99	-429.12	260.16
	2	87.30	99.18	96.54	114.80	-539.56	293.22
	Average	87.74	96.85	98.64	98.89	-484.34	276.69
Ground	3	84.78	89.10	95.83	94.28	-514.94	236.45
	4	93.00	94.55	97.40	76.63	-188.51	224.30
	Average	88.89	91.82	96.61	85.45	-351.72	230.37
Ear	5	92.32	96.04	98.18	106.98	-255.50	295.55
	6	101.62	100.63	101.15	-----	6.93	287.02
	Average	96.97	98.33	99.66	106.98	-124.28	291.28

It is evident from a study of Table 41 that the digestion coefficients obtained for the corn preparations are valuable for comparisons only. It would be ridiculous to say that out of 100 per cent of the amount of a nutrient given to an animal, 106 per cent is digested. No explanation as to why the coefficients for crude fiber and ash run wild is attempted. Alfalfa hay contains relatively large amounts of both crude fiber and ash, whereas corn is comparatively low in these constituents. On account of this fact, any error which occurs in the determinations of the coefficients of digestibility for the alfalfa alone is greatly magnified in the calculation of the coefficients for the grain.

Some differences in the coefficients of digestibility may be accounted for by the differences in the individuality of the animals themselves.

A comparison of averages in Table 41 shows that ear corn apparently has a higher digestibility for crude protein, nitrogen-free extract, ether extract, ash, and crude fiber, than either of the other two forms of corn. Except for the coefficients for crude fiber and dry matter, shelled corn seems to have a greater digestibility for this trial than has ground corn. In regard to the protein, it will be noticed that one of the lambs receiving ground corn gave the lowest coefficient of any of the six lambs. On the whole, a comparison of the digestion coefficients for the grain shows that in this trial ear corn is slightly more digestible than shelled corn, and that both ear corn and shelled corn are slightly more digestible than ground corn. It will be remembered from the account of the feeding trial that the relative fattening values of these three forms of corn were in the order named here. Whole corn produced the greatest gains, shelled corn a close second, and ground corn a poor third.

Reasons for a decrease in digestibility resulting from grinding corn for fattening lambs are at best only a matter of conjecture. Possibly the lambs do not spend sufficient time in masticating finely ground corn to allow the enzymes in the saliva to carry out the work of the conversion of starch into sugar to completion. It may be that finely ground corn does not remain in the stomach of a lamb as long as whole corn does, thus reducing the time during which the digestive juices act on the food.

Summary

In these trials:-

1. The shelling of corn did not increase its fattening value for lambs when fed with alfalfa hay.
2. The grinding of corn seemingly affected a decrease in its fattening value for lambs when fed with alfalfa hay.
3. The amount of water drunk was not an indication of the rate of gain.
4. The digestibility of corn for fattening lambs, when fed with alfalfa hay, was not increased by either shelling or grinding.

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Kans. Sta. Bul. 103
Ontario Sta. Report, 1898
Wyo. Sta. Bul. 69
Wyo. Sta. Bul. 78
So. Dak. Sta. Bul. 114
Nevada Sta. Bul. 66
Utah. Sta. Bul. 58
Minn. Sta. Bul. 80
N. Y. (Cornell) Sta. Bul. 8

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Acknowledgement is due Howard Hackedorn, Ass't. Professor of Animal Husbandry; D. J. Griswold, Research Ass't. in Animal Husbandry; and C. R. Moulton, Ass't. Professor of Agricultural Chemistry, who have furnished invaluable assistance in the compilation and revision of the data herein presented.

UNIVERSITY OF MISSOURI
COLUMBIA

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF AGRICULTURAL CHEMISTRY

May 20, 1916.

Dean Walter Miller,
Graduate School.

Dear Dean Miller:

As per your letter of the 16th I have examined the dissertation of James French Wilson on "'Corn preparation for Fattening Lambs'". This thesis is very largely historical and contains a great deal of data which is not germane to the particular title of the thesis. For example, he has ten or twelve pages dealing entirely with the work of other experiment stations on the digestibility of alfalfa hay.

In his experimental data the feeding experiment with the lambs gives some very interesting and valuable information.

As is brought out by Mr. Wilson in his thesis the results of the digestion trials are of no value for study as to the real digestion coefficients, but are only of value as comparing relatively the one ration with another, because of his failure to save and analyze the refused hay. Had this important data been secured the value of the experiment would have been very greatly enhanced.

I recommend that the thesis be accepted as fulfilling the requirement for the Master's degree.

Yours truly, *O. F. Lowbridge*

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