DIGESTIBILITY OF COTTONSEED HULLS BY STEERS

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF ANIMAL SCIENCE

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1966

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ACKNOWLEDGMENTS

The author, with the highest of esteem, wishes to express most appreciative gratitude to his major professor, Dr. William H. Hale, for his constructive criticism, and guidance throughout the course of this study and the writing of this thesis.

Sincere appreciation goes to Sonia Santee for her help and assistance on laboratory procedures, and to Robert Nunez for his assistance in care of the steers throughout the study.

Special thanks go to Mr. Parke Gilbert for the cooperation and encouragement received at all times.

The author would also like to express his gratitude to Drs. Bruce Taylor and Brent Theurer and the staff of the Animal Science Department for the encouragement received.

Financial support of this study by certain cottonseed processers in Arizona and California is acknowledged.

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ABSTRACT

A digestion study in two phases was conducted with beef steers to determine the digestibility of cottonseed hulls. In phase I, ground alfalfa hay was fed to 12 steers and the digestion coefficients were determined directly. In phase II, a ration of ground alfalfa hay and varying percentages of cottonseed hulls were fed to the same 12 steers and digestion coefficients for cottonseed hulls were determined by difference.

It was found that the total digestible nutrient value of cottonseed hulls was less than the usual accepted values. The average total digestible nutrient value of the cottonseed hulls in the present study on a 90% dry matter basis was 34.0% as compared to the older values of 43.6%. These data show a significant difference in the digestion of crude fiber and nitrogen free extract when determined by the acid detergent and Weende crude fiber methods. The amount of lint remaining on the cottonseed hulls appears to be the most important factor in determining the total digestible nutrients of the entire hull. The bran portion appeared to be highly undigestible, probably due to its high lignin content.

INTRODUCTION

Cattle and cotton production are the primary agriculture industries in Arizona. The rapid growth of the cattle feeding industry in California and Arizona from 250,000 on feed January 1, 1950, to over 1,400,000 today has resulted in the need for more roughage. The cotton industry has also had its changes in production over the years with 190,000 tons of seed being produced in Arizona in 1950 compared to 321,000 tons in 1965 (28). With the increase of seed production, cottonseed hull production has followed the same growth. Most cotton oil mills calculate that a ton of whole cottonseed will produce 460 pounds of cottonseed hulls (6). Thus the cottonseed hull production in Arizona for 1965 was approximately 74,000 tons. Most of the cottonseed hulls being produced are used for ruminant feeding.

There have been many changes in Arizona as to the types of roughages produced over the last 15 years. Using 1950 as the base year, silage production from sorghum and corn was 144,000 tons (28). Silage reached its peak in 1957 with 790,000 tons being produced from sorghum and corn but in 1965 there were only 373,000 tons produced. Alfalfa hay has been the primary source of roughage for the cattle feeding industry in Arizona with a production in 1950 of 563,000 tons and nearly doubling to 1,012,000 tons in 1965. Sorghum grain stubble, vegetable waste, citrus waste and other sources of roughages are also being used.

Cottonseed hull production is directly related to tonnages of cottonseed produced each year and the production of cottonseed in Arizona has been decreasing since its peak in 1953 of 442,000 tons. With the increase of government programs which control the acreage of cotton the total production of cottonseed for Arizona in 1965 (2) was 321,000 tons and the expected tonnage for 1966 will be 30 - 35 per cent less. Even so, there will still be a considerable tonnage of cottonseed hulls on the market for uses in livestock feeding.

The digestibility values that are reported for cottonseed hulls were established 37 to 75 years ago. New varieties of cotton, modern production methods, fertilization rates, and processing methods have changed considerably during this same period. All values in use were determined on limited numbers of animals.

It was the purpose of the study reported in this thesis to determine the digestibility of the proximate fractions of cottonseed hulls and to compare these values with the values that are presently in use.

A digestion study was conducted with growing beef cattle to determine the digestibility of cottonseed hulls by difference. In the first phase, alfalfa hay was fed to all twelve animals and its digestion coefficients were determined. In the second phase, various percentages of cottonseed hulls and alfalfa hay were fed and digestion coefficients of cottonseed hulls were determined by difference.

REVIEW OF LITERATURE

Work with the digestibility of cottonseed hulls dates back to 1891 at the Texas Agricultural Experiment Station. Harrington (20) using five steers, reported the following digestion coefficients for cottonseed hulls: dry matter, 41.6; ether extract, 78.0; crude fiber, 41.2; nitrogen free extract, 30.4; and crude protein, 5.7 per cent. He noted considerable individual variation between the steers in the study. The cottonseed hull fractions showed poor digestion except for the ether extract. He believed the effect of hulls on feeding results was largely mechanical but did not explain the mechanical effect.

Emery and Kilgore (9) indicated that there was considerable variation in hull composition from different oil mills and even the same oil mill due to mill variation in processing. These workers, using a cow in late lactation, fed only hulls for eight days prior to a four day collection period and obtained the following digestion coefficients: dry matter, 35.9; crude protein, 27.1; ether extract, 80.6; nitrogen free extract, 40.3; and, crude fiber, 27.1 per cent. Emery and Kilgore (10) in a second trial added another cow and two goats. The digestion coefficients of all four animals involved were averaged, and crude protein was digested to the extent of 6.75; dry matter, 39.8; ether extract, 85.1;

nitrogen free extract, 30.8; and crude fiber, 43.1 per cent. When cottonseed hulls were fed with cottonseed meal in ratios of 28-1, 3-1, 2-1, Emery and Kilgore (11) found digestion coefficients for cottonseed hulls as follows: dry matter, 36.02; crude protein, 0.25; ether extract, 2.18; nitrogen free extract, 12.20; and crude fiber, 20.61 per cent.

Fraps (13) (14) (15) determined cottonseed hull digestion with sheep and reported protein digestion as a negative value suggesting that the addition of cottonseed hulls lowered the digestion of protein of other feedstuffs fed with them. In direct digestion studies where cottonseed hulls were fed alone the digestion coefficients were: crude protein, 7.4; ether extract, 75.2; nitrogen free extract, 45.0; and crude fiber, 44.5 per cent. In studies where cottonseed hulls were fed with alfalfa hay, protein digestion was, 0; ether extract, 88.6; nitrogen free extract, 59.9; and crude fiber, 55.0 per cent. When cottonseed hulls were fed with cottonseed meal protein digestion was, 15.6; ether extract, 75.1; nitrogen free extract, 54.1; and crude fiber, 49.3 per cent. This work suggests that the digestion of the different nutrient fractions of cottonseed hulls is affected by the feedstuff with which it is being fed.

Tillman *et al* (32) studying the effect of alfalfa ash upon the digestibility of cottonseed hulls by sheep found marked improvement of all nutrient constituents of the ration containing cottonseed hulls by the addition of 28 grams of alfalfa ash per head per day. The ration was a semi-purified ration in which all minerals except calcium, phosphorus, sodium, chlorine and sulphur were supplied by cottonseed hulls.

Lush et al (22) comparing cottonseed hulls and grass hays concluded that cottonseed hulls supplemented with calcium, green feed and protein are superior to hill land carpet and bermuda grass hay and almost equal to high quality bermuda, but inferior to mixed clover for milk production. He suggested that digestion of cottonseed hulls may be higher on well balanced rations.

Neale (27) concluded that grinding hulls did not improve their digestibility by sheep. The rations consisted of cottonseed hulls plus one pound of cottonseed meal per head per day. Serious vitamin A deficiency problems occurred when no vitamin A was added.

Forbes and Garrigus (12) used two fattening rations on five wether-lambs to determine digestion coefficients of a ration containing no hulls with a ration containing hulls. Ration 1 was composed of 44.5 per cent of good quality chopped alfalfa hay and 55.5 per cent of yellow corn. Ration 2 was composed of 50.6 per cent of yellow corn, 15.5 per cent of cottonseed meal, 4.0 per cent of alfalfa leaf meal, 29.9 per cent of cottonseed hulls and 10 per cent molasses. The rations were so compounded as to be nearly equal in gross nutrient content. It was determined that the lambs on the ration containing hulls digested 91 per cent as much dry matter, 82 per cent as much protein, 117 per cent as much fat, 92 per cent as much nitrogen free extract, and 93 per cent as much energy as on the alfalfa hay, corn ration. The lowered digestibility of the ration containing cottonseed hulls was attributed to the amount of lignin in the hulls. The alfalfa hay-corn ration contained 4.40 per cent lignin and the ration containing cottonseed hulls contained 9.45 per cent lignin.

Garrigus (16) using three test pens of 10 lambs each, fed three different fattening rations. Ration 1 contained 55.6 per cent of corn and 44.4 per cent of ground alfalfa hay. Ration 2 contained 50.6 per cent of corn, 26.9 per cent of cottonseed hulls, 3.0 per cent of molasses, 15.5 per cent of cottonseed meal, and 4.0 per cent of dehydrated alfalfa meal. Ration 3 contained 55.6 per cent of corn, 28 per cent of cottonseed hulls and 16.4 per cent of cottonseed meal. He concluded that one hundred pounds of cottonseed hulls will replace about eighty pounds of U.S. No. 1 alfalfa hay in producing gain on lambs fattened in drylot. The supplemented hull rations were approximately 82 per cent as efficient in supplying digestible crude protein and 93 per cent as efficient in supplying metabolizable energy to fattening lambs as was a standard ration designated by ration number one. He suggested that hulls could be used as a roughage for fattening lambs or cattle provided carotene, protein, and minerals are adequately supplied.

Blizzard (4) (5) in a fattening trial with Hereford steer calves found that the substitution of cottonseed hulls for prairie hay gave similar daily gains and feed requirements.

Hale et al (17) comparing cottonseed hulls and alfalfa hay for fattening steers observed that feed consumption and daily gains were increased when 75 per cent of the alfalfa hay was replaced with cottonseed hulls. Feed requirements were lowest on the alfalfa rations. Cottonseed hulls improved the palatability of the high concentrate ration.

Hale et al (19) studied growing rations containing alfalfa hay, cottonseed hulls and molasses and observed that cottonseed hull or molasses additions to alfalfa hay increased feed intake. Cottonseed hulls in this trial had approximately 70 per cent of the feeding value of alfalfa hay when fed in conjunction with alfalfa hay. It was felt that cottonseed hull rations should give the animals greater capacity for fattening rations to be fed subsequently.

Hale et al (18) incorporated cottonseed hulls in 80 per cent concentrate fattening rations and reported that the addition of 4 per cent tallow improved feed efficiency and increased gains markedly. With three times delinted and regular cottonseed hulls (two times delinted) it was observed that daily gains were similar but feed requirements were higher with the three times delinted hulls.

Schneider (30) lists the digestibility coefficients of cottonseed hulls on a dry matter basis for cattle and reports a range of values as follows: crude protein, 4.7-5.4; crude fiber, 49.8-53.1; ether extract, 2.8-4.1; nitrogen free extract, 36.1-38.4 per cent; and total digestible nutrients, 43.1-47.4 per cent.

Meyer and Lofgreen (23) studying the effect of lignin and crude fiber on the total digestible nutrients of alfalfa hay suggested that as the lignin and crude fiber increased, total digestible nutrient decreased. These workers found that an increase in the per cent nitrogen in alfalfa hay was accompanied by an increase in the total digestible nutrient value. VanSoest (33) showed a close relationship of acid detergent crude fiber and lignin content of forages with dry matter digestibility. His work also indicated that as the ash and carbon content of the acid detergent fiber increased, the dry matter digestibility decreased. He also reported a relationship between per cent nitrogen in the feedstuff and digestibility.

EXPERIMENTAL PROCEDURE

A digestion study was conducted in two phases. Phase I was conducted to determine the digestibility of ground alfalfa hay. Phase II was conducted to determine the digestibility of cottonseed hulls by difference by varying percentages of alfalfa hay and cottonseed hulls in the ration.

Twelve steers were individually penned in 2.44 m. by 4.88 m. concrete floored pens with automatic drinking cups. One half of each pen was covered with shade. The animals were fed twice daily, *ad libitum*, at 7:30 - 8:00 a.m. and at 3:30 p.m. All animals on the trial were fed 21 days prior to the initation of the digestion period. After 21 days of feeding *ad libitum* the steers were placed on constant feed intake for at least 5 days at 90% of the *ad libitum* intake followed by a 7-day total collection period.

The pens and feed bunks were thoroughly cleaned prior to the start of fecal collections. Fecal collections were made at frequent intervals during the day and twice at night, 7:00 p.m. and 10:30 p.m. All feces were collected with a dust pan from the concrete floor and placed in galvanized tubs. Feces from each steer were composited over a 24-hour period, weighed and recorded. After the end of each 24-hour collection, all pens were washed thoroughly before the next 24-hour collection started. Collection pots (galvanized tubs) were washed and dried at the end of each collection period. After thoroughly mixing the 24-hour collection, an aliquot was placed in an aluminum drying pan. The aliquot weighed 450-700 grams regardless of the amount of feces collected during the 24-hour period. The aluminum dry pans were covered with plastic bags to prevent drying of samples while transfering from the weighing station to the drying room. All samples were weighed to the nearest gram and placed in a forced air oven and dried at 45°C. for three days. The dried samples were transferred to plastic bags until all seven aliquots were completed.

Feed samples were collected at each feeding period starting two days prior to the collection period and continuing for five days during the seven day collection period. All feed samples were placed in plastic bags to prevent further drying. Four alfalfa hay samples were composited during phase I and three alfalfa hay samples and three cottonseed hull samples were composited during phase II of the digestion study. The composite samples of feces and alfalfa hay were ground through a 1 mm. mesh screen in a Wiley mill, thoroughly mixed and retained in glass containers for future chemical analyses. These latter samples were immediately dried in a vacuum oven at 70°C. to determine exact dry matter as the original oven drying at 45°C. did not completely dry the samples.

When the cottonseed hulls were ground through the 1 mm. mesh screen with the Wiley mill, it was difficult to get a good sample of the ground material due to separation of the lint from the bran. It was observed that if the cottonseed hulls were ground through a 2 mm. mesh screen that the lint and the bran could be easily separated into two fractions. The fractions could then be reground for laboratory analyses. Proximate analysis and gross energy were determined on both bran and lint fractions and then combined to give the value of the intact cottonseed hulls.

Based on these observations the following procedure was used to separate the cottonseed hulls into the lint and bran portions. Twelve samples of cottonseed hulls were available from various locations.

1. From 3 - 12 sub-samples weighing approximately 300 grams were taken from each of the samples of cottonseed hulls.

2. The sub-samples of cottonseed hulls were ground through a 2 mm. mesh screen in a Wiley mill.

3. The sample was first screened once through a 1.981 mm. (.078 inch) sieve.

4. The sample was screened twice through a 1.41 mm. (.0555 inch) sieve.

5. The separated sample of lint and bran was then weighed to the nearest .1 gram.

6. The percentage of lint and bran was calculated on the basis of the total weight of the two fractions.

7. The lint and bran samples were separately ground through a 1 mm. mesh screen in a Wiley mill and retained for chemical analyses.

Proximate analyses for both feed and fecal samples were as described in A. O. A. C. 8th ed. (3). Gross energy was determined with an adiabatic bomb calorimeter. Crude fiber and lignin were also determined as outlined by the acid detergent method of VanSoest (33).

Digestion coefficients of the alfalfa hay ration and alfalfa hay-cottonseed hull ration fractions were determined by the following formula:

$$\frac{\text{Intake - Output}}{\text{Intake}} \times 100$$

Digestion coefficients for the cottonseed hulls in phase II were determined by difference. The method used in the determination of digestion by difference is outlined in Crampton and Lloyd (8).

Standard deviations and coefficients of variation values were calculated as outlined by Spurr, Kellogg and Smith (31).

True protein digestion coefficients were calculated by using a value of 0.45 grams of metabolic nitrogen per 100 grams of dry matter intake (24).

Digestion Trial Phase I

The twelve Hereford steers weighing approximately 244 kilograms were fed a ration of ground alfalfa hay. The alfalfa hay was processed through a 100 hp. hammer mill containing no screen and was stored on a covered concrete floor. An ample amount of alfalfa hay was ground and stored to last during the five day constant feed intake and seven day collection period. The alfalfa hay was all received at this station from the same Arizona location and sufficient alfalfa hay was delivered on one truck load to last the complete feeding period of both Phase I and II of the digestion study. Free choice block salt was available to each steer at all times.

Digestion Trial Phase II

The same twelve steers used in Phase I were randomly alloted in blocks of three and fed varying percentages of cottonseed hulls and ground alfalfa hay as given below:

Steers 1, 5, 7, 12	80% ground alfalfa	20% cottonseed hulls
Steers 2, 6, 8, 11	60% ground alfalfa	40% cottonseed hulls
Steers 3, 4, 9, 10	40% ground alfalfa	60% cottonseed hulls

The alfalfa hay was processed in the same manner as in Phase I. Sufficient amounts of both alfalfa hay and cottonseed hulls were stored under roof on a concrete floor to last the five day constant feed intake and seven day collection period. Sufficient amounts of cottonseed hulls were purchased at one time from the same Arizona location to last the entire feeding period of Phase II. The cottonseed hulls and alfalfa hay were weighed separately to the nearest 0.1 of a pound and were mixed thoroughly in each feed bunk with a shovel. Ration percentages used were not formulated on a nutritional basis but were designed to give adequate cottonseed hull intake. Prior to the collection period all steers were fed _ad libitum_. Free choice block salt was available to each steer at all times. A mineral mixture of 50 per cent steamed bonemeal and 50 per cent salt was made available to the steers at all times to supply additional mineral intake on the high cottonseed hull rations.

RESULTS AND DISCUSSION

Table 1 presents a summary of the data obtained from the separation of cottonseed hulls from various locations in Arizona and California. There was a large range in the per cent lint and bran from the different samples. This was attributed to several factors: (1) Seed size varies with the variety of cotton with large seeds producing less lint; (2) The more times the seeds are passed through the delinters the less lint is left on the hull; (3) The type of cotton gin the seed is processed through will affect the lint percentage. Two types of gins are used; one type of gin is designed to handled short staple cotton which uses saws to remove lint from the seed. The second is designed to handle long staple cotton which uses brushes to remove the lint from the seed. The brushes will remove practically all the lint from the seed. (4) The time of year when cotton is picked will affect the quality of the cottonseed hulls due to the amount of foreign material mixed with the seed, such as leaves, stems, burrs, etc. (5) Moisture content at the time of delinting will affect the percentage of lint that remains on the hulls. The higher the moisture the higher the per cent lint that remains on the hull.

The separation technique was designed to give a quick, easy evaluation for determining the amount of lint on cottonseed hulls. Even though

Table 1. Average percentages of lint, bran, acid detergent crude fiber and acid detergent lignin of several samples of cottonseed hulls from different locations.

Sample No.[a]	No. of Sub-Samples	By Weight		Standard Deviations	Acid Detergent C. F.[b]			Acid Detergent Lignin[b]		
		Lint	Bran		Entire Hull	Lint	Bran	Entire Hull	Lint	Bran
1[c]	6	24.6	75.4	.91	66.9	81.7	62.0	24.0	16.1	26.5
2	12	18.5	81.5	1.14	64.5	78.8	61.3	21.8	13.4	23.7
3	6	18.7	81.3	.45	66.7	80.3	63.6	24.7	17.3	26.3
4	6	21.3	78.7	.79	68.9	81.9	65.3	26.6	17.2	29.2
5	6	14.5	85.5	.54	66.7	82.9	64.0	26.4	15.7	28.2
6	6	18.2	81.8	.60	66.1	82.3	62.5	23.9	16.3	25.5
7[d]	2	100.0				92.1			1.3	
8	3	14.6	85.4	.23						
9	3	16.5	83.5	.50						
10	6	25.7	74.3	1.09						
11	6	16.4	83.6	.23						
12	3	13.9	86.1	.07						

[a]Companies represented by sample numbers may be found in the Appendix, page 42.

[b]Dry matter basis.

[c]Regular cottonseed hulls (two times delinted) 1, 2, 3, 4, 6, 10, 12. Delinted cottonseed hulls (three times delinted) 5, 8, 9, 11.

[d]Pure cotton lint 7.

there was no relationship between the lint content and the acid detergent crude fiber and lignin content (Table 1) it is believed that the separation technique could be a useful tool in determining cottonseed hull quality. There was very little relationship between the appearance of the cottonseed hulls and the lint content as determined in the separation studies.

It was apparent that the separation technique did not completely separate the lint and bran due to the high acid detergent lignin content of the lint as shown in Table 1. However the technique as used was highly repeatable as shown by the standard deviations for the six subsamples for each sample of hulls. The possibility of using more sieving steps and timing each step of the procedure are possible solutions to further standardizing this technique. It is believed that a procedure such as the one described could be a useful tool in determining the quality of cottonseed hulls in livestock feeding.

The significance of the amount of lint on cottonseed hulls on the nutritional value of the entire hull is apparent due to the fact that lint is essentially 100 per cent cellulose. Pure cellulose is highly digestible by rumen microorganisms (21). The nutritional significance of the per cent lint on cottonseed hulls was demonstrated by Hale et al (18) in a fattening trial with steers on regular (two times delinted) and three times delinted cottonseed hulls. The separation technique described above was used to determine the quality of hulls fed. The regular hulls contained 20.6 per cent lint and the three times delinted hulls contained 14.6 per cent lint. The finishing rations contained 15 per cent cottonseed hulls. There was little difference in the 122 day gains between the two hull rations; however, the feed required per 100 pounds of gain on the delinted hulls was increased by 35 pounds over the regular hulls. This was probably a reflection of the difference in lint content of the hulls.

Abbreviations used throughout this thesis for table headings are found in Table 2.

Digestion Study Phase I

Results of Phase I on the digestibility of the alfalfa hay are reported in Table 3. There was very little steer difference in digestion of any of the nutrients as noted by the low coefficient of variation.

The total digestible nutrients of the alfalfa hay in this study using the acid detergent crude fiber technique compare favorably with those of Amavisca (1) who found 60.97 per cent total digestible nutrients on an Arizona alfalfa hay sample. Saba (29) reported a total digestible nutrient value of 60.61 per cent using the Weende crude fiber method which compares favorably with 60.14 per cent for the same method with the alfalfa hay in this study.

Digestion Study Phase II

The proximate analysis, acid detergent crude fiber, acid detergent lignin and gross energy of the rations are given in Table 4. The digestion

Table 2. Abbreviations used throughout this thesis for table headings.

D. M.	=	Dry matter
E. E.	=	Ether extract
C. P.	=	Crude protein
T. P.	=	True protein
C. F.	=	Crude fiber
A. D. C. F.	=	Acid detergent crude fiber
W. C. F.	=	Weende crude fiber
L.	=	Lignin
N. F. E.	=	Nitrogen-free extract
A. D. N. F. E.	=	Acid detergent nitrogen-free extract
W. N. F. E.	=	Weende nitrogen-free extract
G. E.	=	Gross energy
T. D. N.	=	Total digestible nutrients

Table 3. Digestion coefficients and total digestible nutrients of alfalfa hay using the acid detergent crude fiber and lignin and Weende crude fiber determinations. All values on a dry matter basis with 12 steers averaged.

	D. M. %	C. P. %	T. P. %	C. F. %	L. %	E. E. %	N. F. E. %	G. E. %	T. D. N. %
				Acid Detergent Crude Fiber					
Alfalfa hay	59.97	70.24	86.83	47.27	11.27	73.16	71.67	59.68	60.18
Standard Deviation	1.20	0.62	0.62	1.98	2.91	1.33	0.95	1.20	1.12
Coefficient of Variation	2.00	0.88	0.71	4.18	2.58	1.81	1.32	2.01	1.87
				Weende Crude Fiber					
Alfalfa hay	59.97	70.24		47.47		73.16	67.23	59.68	60.14
Standard Deviation	1.20	0.62		2.15		1.33	1.32	1.20	1.12
Coefficient of Variation	2.00	0.88		4.53		1.81	1.96	2.01	1.87

Table 4. Proximate analysis and gross energy of alfalfa hay, cottonseed hulls and combined rations using the acid detergent crude fiber and lignin and Weende crude fiber methods. All analysis on a dry matter basis. Phase II.

	C.P. %	C.F. %	L. %	E.E. %	Ash %	N.F.E. %	Gross Energy cal./gm.
				Acid Detergent Crude Fiber			
Alfalfa hay	17.54	38.36	7.97	6.21	10.47	27.42	4593
Cottonseed hulls	5.36	64.52	21.81	1.58	3.21	25.33	4473
80% alfalfa hay 20% hulls	15.10	43.59	10.74	5.28	9.02	27.00	4569
60% alfalfa hay 40% hulls	12.67	48.82	13.51	4.36	7.57	26.58	4545
40% alfalfa hay 60% hulls	10.23	54.04	16.27	3.43	6.11	26.17	4521
				Weende Crude Fiber			
Alfalfa hay	17.54	31.66		6.21	10.47	34.12	4593
Cottonseed hulls	5.36	46.98		1.58	3.21	42.87	4473
80% alfalfa hay 20% hulls	15.10	34.73		5.28	9.02	35.87	4569
60% alfalfa hay 40% hulls	12.67	37.79		4.36	7.57	37.62	4545
40% alfalfa hay 60% hulls	10.23	40.85		3.43	6.11	39.37	4521

coefficients and total digestible nutrients of the various combinations of alfalfa and cottonseed hulls are reported in Table 5.

From the data presented in Table 5, it can be seen that as the per cent of cottonseed hulls increases the digestibility of ration dry matter, crude protein, crude fiber, gross energy and total digestible nutrients decreases with the acid detergent crude fiber method. Ether extract and nitrogen free extract digestibility increased as the per cent of cottonseed hulls was increased in the ration when determined by the acid detergent method.

The digestion coefficients of the combined rations when determined by the Weende crude fiber method gave different values for crude fiber and nitrogen free extract when compared to the acid detergent crude fiber method. The ether extract and crude fiber digestion increased as the per cent of cottonseed hulls was increased in the ration. All other fractions decreased. These findings indicate that the cottonseed hull fractions of crude protein, dry matter, nitrogen free extract and gross energy are less digestible than those of alfalfa hay. The lowered digestion of nitrogen free extract with the Weende crude fiber method can be explained by the fact that by this method of crude fiber determination much of the lignin remains in the nitrogen free extract fraction.

Digestion of the cottonseed hulls by difference was determined as described by Crampton and Lloyd (8). To determine the digestibility of

Table 5. Digestion coefficients and total digestible nutrients of the alfalfa hay and cottonseed hull rations using the acid detergent and Weende crude fiber methods. All values on a dry matter basis.

	No. Steers	D. M. %	C. P. %	C. F. %	L. %	E. E. %	N. F. E. %	G. E. %	T. D. N. %
				Acid Detergent Crude Fiber					
80% alfalfa hay 20% hulls	4	51.69	60.08	36.50	-8.55	69.97	71.02	51.75	52.96
60% alfalfa hay 40% hulls	4	49.32	52.87	35.68	-5.02	74.71	71.78	49.63	50.47
40% alfalfa hay 60% hulls	4	46.94	41.13	35.11	-0.54	77.37	73.10	47.06	48.28
				Weende Crude Fiber					
80% alfalfa hay 20% hulls	4	51.69	60.08	39.64		69.97	59.45	51.75	52.48
60% alfalfa hay 40% hulls	4	49.32	52.87	40.64		74.71	56.04	49.63	50.47
40% alfalfa hay 60% hulls	4	46.94	41.13	41.24		77.37	53.99	47.06	48.28

some diet component by indirect procedures, two or more digestion trials are necessary. In one the "basal" diet without the feedstuff in question is fed and the digestibility of its nutrients determined. The same basal diet is then fed with the addition of the feed to be tested and digestion of nutrients determined. The assumption is made that mixing the two feeds together does not alter the digestibility of the nutrients in either feed. The amount of the proximate fraction in the feces from the basal portion is calculated. The remaining fecal fraction is presumed to come from the feed being tested.

Digestibility by difference was calculated by the following equations:

$$\text{Amount of proximate fraction of basal feed} - \left(\text{Amount of proximate fraction of basal feed} \times \text{digestibility}\right) =$$

Amount of proximate fraction in feces from basal feed.

Total proximate fraction in feces - Proximate fraction from basal feed = Amount of proximate fraction of test feed in feces.

$$\frac{\text{Intake of proximate fraction of test feed} - \text{Fecal proximate fraction of test feed in feces}}{\text{Intake of proximate fraction of test feed}} \times 100 = \text{digestibility of proximate fraction of test feed.}$$

There are two values reported in this study for total digestible nutrients and even though these values are similar they are reported separately. The first method was calculated by the following equation:

Total gms. hay in ration X % total digestible nutrients in hay =

Gm. total digestible nutrients in hay.

Total gms. ration X % total digestible nutrients in ration =

Gm. total digestible nutrients in ration.

$$\frac{\text{Total digestible nutrients in ration} - \text{Total digestible nutrients in hay}}{\text{Total gms. cottonseed hulls in ration}} \times 100 =$$

% total digestible nutrients in cottonseed hulls.

The second method was calculated by multiplying each proximate nutrient fraction of cottonseed hulls by its digestion coefficient and total digestible nutrients were calculated directly.

Digestion values for the cottonseed hulls were calculated for each steer on the basis of the digestion coefficient of alfalfa hay for each individual steer rather than an average digestion coefficient for all 12 steers. Digestion coefficients of cottonseed hulls as determined by difference for each of the levels of cottonseed hulls fed are given in Table 6. Considerable variation was observed in the 80 per cent alfalfa hay-20 per cent cottonseed hull level. The digestion of the proximate nutrient fractions of cottonseed hulls were increased as the per cent of hulls were increased in the ration. It is felt that in the 20 per cent hull treatment there was not sufficient hulls in the ration to get accurate measurement of the digestion of the cottonseed hull fraction by difference.

Table 6. Digestion coefficients and total digestible nutrients of cottonseed hulls determined by difference using the acid detergent crude fiber method. All values on a dry matter basis.

	No. Steers	D. M. %	C. P. %	C. F. %	L. %	E. E. %	N. F. E. %	G. E. %	T. D. N. % a	T. D. N. % b
80% alfalfa hay 20% hulls	4	19.37	-74.83	13.44	-32.66	35.22	69.11	22.28	26.57	23.06
Standard Deviation		16.52	46.52	14.20	22.70	36.62	17.52	19.34	12.81	15.90
Coefficient of Variation		85.3	62.17	105.7	69.50	103.9	25.4	86.8	48.2	68.9
60% alfalfa hay 40% hulls	4	33.18	-32.84	25.67	-12.50	84.54	71.96	34.25	36.36	36.03
Standard Deviation		5.00	11.94	2.76	8.51	11.53	14.85	4.59	4.72	4.55
Coefficient of Variation		15.1	36.36	10.8	68.1	13.6	20.6	13.4	13.0	12.6
40% alfalfa hay 60% hulls	4	37.68	-22.08	29.74	-3.78	86.08	74.01	37.98	39.92	39.81
Standard Deviation		3.31	5.40	3.27	4.99	1.81	6.02	2.97	3.32	3.34
Coefficient of Variation		8.9	24.46	11.0	13.20	2.1	8.1	7.8	8.3	8.4

[a] T. D. N. by difference.

[b] T. D. N. calculated.

Digestion coefficients as determined by difference irrespective of the cottonseed hull level for the 12 steers are reported in Table 7. The variation observed with all 12 steers was high because of the variation in the 80-20 treatment as was shown in Table 5. In Table 8 the two steers with low digestion coefficients have been deleted because they showed such a wide difference from the other 10 steers. The coefficient of variation was reduced considerably when these steers were omitted.

The crude protein digestibility of the hulls as determined by difference was -30.88 per cent. However, true protein digestibility of the hulls was 18.98 per cent (Table 8). This can be accounted for by the fact that feed intake on the hull rations was increased by 19.3 per cent when compared to the alfalfa rations and protein intake was decreased by 14.5 per cent. Thus, on the hull rations, due to the high feed intake, a larger portion of the fecal protein was from metabolic origin than on the alfalfa ration. In addition the higher crude fiber levels on the hulls ration, compared to the alfalfa, probably increased the metabolic nitrogen independent of dry matter intake although no estimate of that factor can be determined from these studies.

There was considerable steer variation in ether extract digestibility. The results indicate that the ether extract of cottonseed hulls was highly digestible. However, the per cent true fat in the ether extract of cottonseed hulls is not known. The values obtained were similar to those

Table 7. Digestion coefficients and total digestible nutrients of cottonseed hulls as determined by difference using the acid detergent and Weende crude fiber methods. Average of 12 steers. All values on a dry matter basis.

	D. M. %	C. P. %	C. F. %	L. %	E. E. %	N. F. E. %	G. E. %	T. D. N. % a	T. D. N. % b
				Acid Detergent Crude Fiber					
Cottonseed hulls	30.09	-43.25	22.93	-16.31	68.61	71.69	31.50	34.29	32.97
Standard Deviation	12.25	34.67	10.60	18.00	60.90	12.58	12.61	9.41	11.56
Coefficient of Variation	40.70	80.16	46.23	110.4	88.76	17.54	40.03	27.45	35.08
				Weende Crude Fiber					
Cottonseed hulls	30.09	-43.25	31.31		68.61	41.50	31.50	33.33	32.53
Standard Deviation	12.25	34.67	10.12		60.90	11.47	12.61	11.53	11.80
Coefficient of Variation	40.70	80.16	32.32		88.76	27.64	40.03	34.59	36.27

[a]T. D. N. by difference.

[b]T. D. N. calculated.

Table 8. Digestion coefficients and total digestible nutrients of cottonseed hulls as determined by difference using the acid detergent and Weende crude fiber methods. Average of 10 steers. All values on a dry matter basis.

	D.M. %	C.P. %	T.P. %	C.F. %	L. %	E.E. %	N.F.E. %	G.E. %	T.D.N. % a	T.D.N. % b
Acid Detergent Crude Fiber										
Cottonseed hulls	34.92	-30.88	18.98	27.27	-10.31	76.86	74.42	36.46	37.94	37.41
Standard Deviation	4.48	11.69	12.70	3.42	8.39	48.23	10.26	4.45	4.35	4.71
Coefficient of Variation	12.81	37.86	66.91	12.52	81.43	62.75	13.78	12.44	11.47	12.58
Weende Crude Fiber										
Cottonseed hulls	34.92	-30.88		35.26		76.86	45.56	36.46	37.74	37.07
Standard Deviation	4.48	11.69		3.64		48.23	6.87	4.54	4.69	4.82
Coefficient of Variation	12.81	37.86		10.32		62.75	15.08	12.44	12.44	13.00

[a] T.D.N. by difference.

[b] T.D.N. calculated.

reported by Harrington (20) working with southern feedstuffs, who reported ether extract digestion of 74.7 per cent for cottonseed hulls. Fraps (15) reported the digestion of ether extract of cottonseed hulls as 75.2 and 92.9 per cent on two different animals.

Nitrogen free extract as determined by the acid detergent crude fiber method gave a lower proximate analysis value than the Weende crude fiber method but the digestion of nitrogen free extract was much higher on the acid detergent method. This can be explained since in the Weende crude fiber method of crude fiber determination a considerable portion of the lignin is included in the nitrogen free extract fraction. With the acid detergent crude fiber method the lignin is included in the fiber fraction. By the Weende method approximately 80 per cent of the lignin was calculated to be in the nitrogen free extract fraction. Fraps (15) showed considerable variation of nitrogen free extract digestion of cottonseed hulls with sheep and reported values of 55.4, 62.0 and 45 per cent. Emery and Kilgore (9) reported values for cattle of 40.3 and 45.7 per cent and for sheep, 28.0 and 30.8 per cent. All of the previous work indicated fairly low nitrogen free extract digestion. In this study the nitrogen free extract digestion values determined by the Weende method were in the same area as those previously reported, which was 41.5 per cent when calculated with 12 steers and 45.6 per cent calculated using 10 steers.

Crude fiber digestion was directly related to the method of determination. The Weende method showed digestion values of 31.31 and 35.26 per cent using 12 and 10 steers, respectively. The acid detergent crude fiber method gave corresponding values of 22.93 and 27.27 per cent digestion. Here again this is explained by the fact that lignin is included in the crude fiber fraction when determined by the acid detergent method. Lignin is usually considered undigestible and no digestion of lignin is shown for cottonseed hulls. However, alfalfa hay showed a lignin digestion of 11.0 per cent. Cottonseed hulls contained 21.81 per cent lignin which is very high and reflects the high percentage of crude fiber in cottonseed hulls by the acid detergent crude fiber method. This study showed a lignin digestion of cottonseed hulls of -10.31 per cent and -16.31 per cent for 10 and 12 steers, respectively. These results suggest that the lignin of cottonseed hulls is less digestible than that of alfalfa hay.

Previous work on crude fiber digestion with the Weende method indicated a range of 27.0 per cent and 41.2 per cent digestion. The value of 35.3 per cent in this study agrees with earlier studies. The crude fiber content of the hulls in this study was quite different by the two methods of determination. The acid detergent crude fiber method gave a value of 64.52 per cent and the Weende crude fiber method gave a value of 46.98 per cent.

Dry matter digestion of 34.92 per cent was calculated in this study using 10 steers and this value was similar to that reported by Emery and Kilgore (9) of 35.9 per cent. When all 12 steers were used a value of 30.09 dry matter digestion was found.

The total digestible nutrients as determined by method one in the preceeding discussion gave values for the 12 steers at 33.33 per cent and 34.29 per cent for the Weende crude fiber and acid detergent crude fiber methods, respectively. When only 10 steers were used values of 37.74 per cent for the Weende crude fiber method and 37.94 per cent for the acid detergent crude fiber methods were found.

The values reported using the second method of calculating total digestible nutrients gave values of 32.97 per cent and 37.41 per cent for 12 and 10 steers, respectively, when calculated by the acid detergent crude fiber method. Total digestible nutrient values for 12 and 10 steers were 32.53 per cent and 37.07 per cent, respectively, when calculated by the Weende crude fiber method. The total digestible nutrient values are lower than those reported in Morrison (25) of 43.7 per cent and Schnieder (30) of 43.1-47.4 per cent.

One can conclude that cottonseed hulls have changed in digestibility since the original digestion studies which may be in part due to variety changes, improved cultural practices and processing methods. Low digestibility of cottonseed hulls is understandable due to the high amount of lignin they contain. Analysis of hulls used in this study indicates that the lignin is a fraction of the bran rather than the lint. Forbes and Garrigus (12) have shown a high negative correlation between lignin content and digestibility for pasture forages. VanSoest (33) working on forages of known digestibility demonstrated a lowered digestibility of dry matter as the acid detergent crude fiber and lignin content increased in a feedstuff. All previous values reported for crude fiber of cottonseed hulls have been by the Weende procedure of determination. Forbes and Garrigus (12) related the lowered digestibility of cottonseed hulls in some of their studies to the increasing amounts of lignin in the rations.

GENERAL DISCUSSION

Table 9 shows digestion coefficients for various fractions and total digestible nutrients of cottonseed hulls as determined in the present study in comparison with corresponding values for Morrison (25), Schneider (30) and Feed Lot Magazine (26). It is apparent that the nutritive value of cottonseed hulls in this study as measured by total digestible nutrients is considerably less than the values frequently used. The usually accepted values are based on averages obtained from several species of animals and are from 30-70 years old. The types of cottonseed hulls used in the early digestion studies are not known but it is generally believed that present day cottonseed hulls contain considerably less lint than those previously studied. If present day hulls contain less lint than older type hulls, then the nutritive value would be expected to be lower. The lint is considered to be pure cellulose and as such is highly digestible by rumen microorganisms. The high lignin content of the bran portion of the cottonseed hull as determined by the acid detergent lignin method was surprising based on lignin values normally given for hulls. It is believed, however, that the lignin values determined in this study were a true reflection of the lignin value of the bran and subsequently the entire hull. It is known that digestibility of the crude fiber of roughages has an inverse relationship to its lignin content (21).

Table 9. Digestion coefficients and total digestible nutrients of cottonseed hulls as determined by this study compared with accepted values.

	D. M. %	C. P. %	C. F. %	E. E. %	N. F. E. %	G. E. %	T. D. N.[a] %
Morrison (25) Weende Crude Fiber	-	0	51.0	78.0	50.0	-	43.3
Schneider (30) Weende Crude Fiber	-	6	48.3	81.0	34.0	-	43.9
Feed Analysis Table Feed Lot Magazine (26)	-	-	-	-	-	-	38.9
Current Study[b]							
Acid Detergent Crude Fiber	34.9	-30.9	27.3	76.9	74.4	36.5	34.1
Weende Crude Fiber	34.9	-30.9	35.3	76.9	45.6	36.5	34.0

[a]Total digestible nutrients on a 90% dry matter basis.

[b]All values reported for 10 steers.

The differences noted between the crude fiber digestion coefficients in the present study as determined by acid detergent crude fiber and those reported in textbooks appear to be due to the method of crude fiber determination. The differences noted with the Weende method in this study and the Weende method reported in the textbooks may be due to the differences in lint content of the present hulls as compared to older type hulls. If the assumption is made that the older type hulls contain more lint then the higher crude fiber digestibility values in textbooks can be explained.

The lint and bran separations did not completely separate the bran from the lint. It appears that there was very little lint remaining with the bran portion but considerable bran remained with the lint portion as indicated by the high lignin content of the lint. If the assumption is made that the lint contains little or no lignin then the per cent bran in the lint portion can be calculated as the lignin value would represent bran contamination in the lint. These calculations indicate that the lint actually contained 57 per cent bran by weight. If this is added to the bran portion and the assumption is made that the bran contains little or no lint then the lint content of the cottonseed hulls in sample 2 would be only 8-10 per cent rather than 18.5 per cent as indicated in Table 1. If the lint is considered completely digested, it is apparent that the total digestible nutrient value of the bran is very low. It was estimated that the bran contains only 27 per cent total digestible nutrients or less which corresponds to a value of 44 per cent given by Morrison (25) for cottonseed hull bran. These calculations were based on 34 per cent total digestible nutrients for the entire hull as shown in Table 9. Following these calculations, hulls which contain 16 per cent lint would then contain 38 per cent total digestible nutrients. The affect of lint content on total digestible nutrients of cottonseed hulls becomes apparent.

Due to the fact that cottonseed hulls do not lend themselves for direct digestibility it would be difficult to determine precisely the nutrient digestibility. The direct values might be of limited use due to the associative affect of other feeds on the digestibility of cottonseed hulls.

The digestion coefficients and total digestible nutrients of the cottonseed hulls are given in Table 10 for determination using the acid detergent crude fiber method and the Weende crude fiber method.

Table 10. Digestibility of cottonseed hulls as determined in the present study.

Item	Coefficient
Dry matter	34.9
Ether extract	76.9
Crude protein	-30.9
True protein	19.0
Acid detergent crude fiber	27.3
Weende crude fiber	35.3
Acid detergent nitrogen-free extract	74.4
Weende nitrogen-free extract	45.6
Gross energy	36.5
Total digestible nutrients[a]	34.0

[a]T.D.N. on a 90% dry matter basis.

SUMMARY

A digestion study was conducted in two phases with cattle to determine the digestion coefficients of the proximate components of cottonseed hulls. Phase I was conducted to determine the digestibility of ground alfalfa hay. Phase II was conducted to determine the digestibility of cottonseed hulls by difference by varying the percentages of alfalfa hay and cottonseed hulls in the ration.

The results of phase I indicated that the values for the digestion coefficients of alfalfa hay agree favorably with those previously determined at the University of Arizona for alfalfa hay grown in Arizona. Total digestible nutrient values of the alfalfa hay in this study were higher than the values reported in standard texts.

In phase II the ration formulation of the alfalfa hay: cottonseed hull mixtures had no significance in relation to nutrient requirements of the animals as the rations were designed to obtain maximum consumption of cottonseed hulls. The results indicated that the per cent lint which remains on cottonseed hulls was very important to the nutritive value of the cottonseed hulls. The lint was considered to be highly digestible as it is essentially pure cellulose. The low digestion coefficients obtained must therefore be attributed to the bran portion of the hulls. The high amount of lignin found in cottonseed hulls was probably the

cause of the low digestion of the hulls, as lignin is considered undigestible by rumen microorganisms.

The method of crude fiber determination had an effect on the digestion of crude fiber and nitrogen free extract. When lignin was calculated in the crude fiber fraction by the acid detergent method the digestion of the crude fiber was low and the digestion of nitrogen free extract was high. When crude fiber was determined by the Weende method a large portion of the lignin was included in the nitrogen free extract and resulted in a higher crude fiber and a lower nitrogen free extract digestibility.

It is evident from this study that the cottonseed hulls being produced today give lower total digestible nutrient values compared to the total digestible nutrient values for cottonseed hulls produced 30-70 years ago. These differences may be a reflection of the changes of varieties of cotton grown, production methods, fertilization rates and processing methods. The average total digestible nutrient value of the cottonseed hulls in the present study on a 90 per cent dry matter basis was 34.0 per cent as compared to the older values of 43.6 per cent.

APPENDIX

Table 11. Source of cottonseed hull samples shown in Table 1.

Sample Number	Company
1	Arizona Cottonseed Products Co., Gilbert, Arizona
2[a]	Casa Grande Cotton Oil Mill, Casa Grande, Arizona
3	Producers Cotton Oil Company, Calipatria, California
4	Producers Cotton Oil Company, Fresno, California
5	Ranchers Cotton Oil Company, Fresno, California
6	Serape Cotton Oil Mill, Chandler, Arizona
7	Cotton Lint Grown in Tucson, Arizona, area
8	Casa Grande Cotton Oil Mill, Casa Grande, Arizona
9	Casa Grande Cotton Oil Mill, Casa Grande, Arizona
10	Casa Grande Cotton Oil Mill, Casa Grande, Arizona
11	Casa Grande Cotton Oil Mill, Casa Grande, Arizona
12	Casa Grande Cotton Oil Mill, Casa Grande, Arizona

[a]Cottonseed hulls fed in this study.

Table 12. Proximate analysis of the alfalfa hay fed during phase I and phase II and cottonseed hulls fed during phase II. Proximate analysis of the bran and lint portions of the cottonseed hulls. All analysis on a dry matter basis.

	C.P. %	C.F. %	L. %	E.E. %	Ash %	N.F.E. %	Gross Energy cal./gm.
			Acid Detergent Crude Fiber				
Alfalfa hay Phase I	16.94	38.26	7.79	5.54	9.89	29.41	4569
Alfalfa hay Phase II	17.54	38.36	7.70	6.21	10.47	27.42	4593
Cottonseed hulls	5.36	64.52	21.81	1.58	3.21	25.33	4473
Bran portion[a]	5.18	61.27	23.72	1.54	3.31	28.68	4490
Lint portion[b]	6.16	78.77	13.44	1.74	2.77	10.55	4400
			Weende Crude Fiber				
Alfalfa hay Phase I	16.94	32.08		5.54	9.89	35.55	4569
Alfalfa hay Phase II	17.54	31.66		6.21	10.47	34.12	4593
Cottonseed hulls	5.36	46.98		1.58	3.21	42.87	4473
Bran portion[a]	5.18	42.51		1.54	3.31	47.46	4490
Lint portion[b]	6.16	66.67		1.74	2.77	22.66	4400

[a]Made up 81.5% of the entire hull by weight.

[b]Made up 18.5% of the entire hull by weight.

Table 13. Proximate analysis and gross energy of feces on ground alfalfa hay ration. All analysis on a dry matter basis.

Steer No.	C. P. %	A. D. C. F. %	A. D. L. %	W. C. F. %	E. E. %	Ash %	A. D. N. F. E. %	W. N. F. E. %	Gross Energy cal. /gm.
1	12.30	51.57	18.00	43.76	3.80	11.70	20.63	28.44	4689
2	12.42	51.24	17.62	41.62	3.88	11.76	20.70	30.32	4611
3	12.34	51.03	18.03	42.02	3.63	11.94	21.06	30.07	4629
4	13.32	49.27	17.28	40.32	3.57	12.37	21.47	30.42	4634
5	12.77	50.52	17.74	42.58	3.60	11.91	21.20	29.14	4610
6	12.77	51.24	17.72	42.44	3.72	11.08	21.19	29.99	4667
7	12.50	51.12	17.73	42.91	4.06	11.34	20.98	29.19	4716
8	12.74	51.39	18.29	42.90	3.78	11.84	20.25	28.74	4624
9	12.53	50.40	17.57	43.20	3.82	12.31	20.94	28.14	4622
10	13.48	49.64	17.76	42.02	3.68	12.20	21.00	28.62	4627
11	12.90	50.66	17.89	42.28	3.74	11.32	21.38	29.76	4596
12	12.48	51.72	18.15	43.32	3.67	11.16	20.97	29.37	4661

Table 14. Proximate analysis and gross energy of feces on ground alfalfa hay and cottonseed hull ration. All analysis on a dry matter basis.

Steer No.	C. P. %	A. D. C. F. %	A. D. L. %	W. C. F. %	E. E. %	Ash %	A. D. N. F. E. %	W. N. F. E. %	Gross Energy cal. /gm.
1[a]	12.29	57.54	23.19	44.07	3.85	10.06	16.26	29.73	4590
2[b]	11.12	60.71	25.63	43.81	2.33	9.37	16.47	33.37	4523
3[c]	10.84	64.65	28.91	43.85	1.47	7.88	15.16	35.96	4503
4[c]	11.72	66.09	31.02	43.96	1.52	8.54	12.13	34.26	4535
5[a]	12.16	57.96	22.90	42.76	3.03	11.18	15.67	30.87	4546
6[b]	11.71	61.28	26.68	42.56	2.18	9.10	15.73	34.45	4510
7[a]	12.86	56.12	24.19	42.79	3.26	10.50	17.26	30.59	4633
8[b]	12.62	65.55	31.09	46.80	2.04	9.27	10.52	29.27	4532
9[c]	11.13	66.28	30.16	45.81	1.51	8.16	12.92	33.39	4475
10[c]	11.79	67.71	32.32	47.72	1.36	6.55	12.59	32.58	4534
11[b]	11.64	61.53	27.04	44.53	2.14	8.66	16.03	33.03	4505
12[a]	12.60	57.82	24.27	44.22	3.02	11.14	15.42	29.02	4475

[a]Steers on 80% ground alfalfa hay and 20% cottonseed hulls.

[b]Steers on 60% ground alfalfa hay and 40% cottonseed hulls.

[c]Steers on 40% ground alfalfa hay and 60% cottonseed hulls.

Table 15. Feed consumed and feces excreted during the seven-day digestion trial for both phases. All values on a dry matter basis.

Animal No.	Gms. Fed		Gms. excreted
	Alfalfa Hay	Cottonseed Hulls	
	Phase I		
1	44,910		18,323
2	39,294		15,826
3	39,294		15,831
4	44,910		17,502
5	44,910		18,214
6	44,910		17,824
7	33,682		13,311
8	39,294		15,250
9	39,294		15,999
10	39,294		14,433
11	44,910		18,154
12	44,910		17,760
	Phase II		
1[a]	41,362.6	10,440.6	24,225
2[b]	30,921.5	20,909.9	26,400
3[c]	20,854.0	31,004.1	28,407
4[c]	20,854.0	31,004.1	25,973
5[a]	41,362.6	10,440.6	25,992
6[b]	30,921.5	20,909.9	27,485
7[a]	32,359.8	7,931.4	20,889
8[b]	27,670.8	18,400.6	21,874
9[c]	18,351.6	27,745.3	25,397
10[c]	18,351.6	27,745.3	24,103
11[b]	30,921.5	20,909.9	26,577
12[a]	41,362.6	10,440.6	23,027

[a]Steers on 80% ground alfalfa hay and 20% cottonseed hulls.
[b]Steers on 60% ground alfalfa hay and 40% cottonseed hulls.
[c]Steers on 40% ground alfalfa hay and 60% cottonseed hulls.

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