PROTEIN SUPPLEMENTS FOR SHEEP AS DETERMINED BY GROWTH, DIGESTIBILITY AND NITROGEN RETENTION

by

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PART I

NUTRITIVE VALUE OF COTTONSEED MEAL OF HIGH AND LOW NITROGEN SOLUBILITY, SESAME MEAL AND A COMBINATION OF SOYBEAN OIL MEAL AND SESAME MEAL

INTRODUCTION

All proteins do not have the same nutritive value for simple-stomached animals. Differences in nutritive value or quality between proteins are due mainly to differences in amino acid make-up. The early works of Osborne and Mendel (1911, 1912, 1913) on pure proteins were important in establishing these facts. The excellent review by Boas Fixsen (1935) summarizes the early work in this field.

The requirements of cattle and sheep for protein and the comparative value of protein from different sources have been investigated by numerous workers. Such investigations with ruminants are complicated by the synthesis of amino acids from both protein and non-protein nitrogen compounds by the rumen microorganisms (Loosli et al., 1949). Hart and Humphrey (1915) were among the first American workers to study protein quality in rations for dairy cattle. They found milk protein would support a higher nitrogen balance during lactation than corn or wheat protein. In a second study (Hart and Humphrey, 1916) a difference was found in efficiency of utilization of gluten feed, as compared to soybean oil meal, distillers grains, casein and skim milk powder by dairy cows. In the latter study the supplements furnished 50 percent of the digestible protein in the ration. Swanson and Herman (1943) have discussed the limitations and difficulties of studies of this nature with dairy animals.

In 1924 the importance of protein quality studies was emphasized in a report by H. H. Mitchell. He discussed the determination of the biological value of protein which was suggested earlier by Thomas (as cited by Mitchell, 1924a). Mitchell (1924b) presented data showing that for rats different proteins have different biological values and (Mitchell, 1924c) that supplementary effects exist between the proteins of corn and milk and of corn and tankage.

The nutritive value of proteins from various sources for lambs was investigated in a series of studies at the Cornell Agricultural Experiment Station. Turk et al. (1934) found the proteins from alfalfa hay and clover hay to be approximately equal in nutritive value for lambs. In later studies with lambs Turk et al. (1935) designed a basal ration to furnish about 1 percent protein. The composition of the basal ration, in percent, was as follows: wheat straw, 25; regenerated cellulose, 9.7; starch, 17.4; sugar, 17.3; corn oil, 4.0; and salt mixture, 3.0. Soybean oil meal, linseed meal and corn gluten meal were added to the basal ration to bring the total protein content to 11 percent. The lambs were more efficient in storing protein from soybean oil meal (33.8% of the intake) than from either linseed meal (26.7%) or corn gluten meal (26.5%). The biological value of the protein in the soybean oil meal, linseed meal and corn gluten meal rations was 72.8, 67.7 and 65.7, respectively. The value for soybean oil meal was significantly higher than that for the other two meals. However, Turk et al. (1935) questioned whether such differences would be of consequence in mixed rations containing protein from several sources.

Miller et al. (1937) studied soybean oil meal, linseed meal, and corn gluten meal as supplements to timothy hay and corn stover for lambs. Differences between values obtained with the supplements added to either corn and timothy hay rations or corn and corn stover rations were not significant. In 1942, Miller and Morrison summarized data from over

325 nitrogen balance trials with lambs and concluded that for lambs there is little or no difference in the quality of protein furnished by most feed stuffs. This is in agreement with the statement of Johnson et al. (1942), "the similarity in the metabolic utilization of urea, soybean oil meal and casein by ruminants is constant with the theory that a considerable proportion of the protein ultimately utilized by the ruminant is microorganismal protein, regardless of the nature of the nitrogen compounds contained in the ration consumed."

Briggs et al. (1946a) supplemented a basal ration composed of 600 gm. of prairie hay and 10 gm. salt with 73.4 gm. of soybean oil meal, cottonseed meal, peanut meal or a combination of the three meals. The percentage nitrogen stored by lambs during the 10-day collection period on the cottonseed meal, peanut meal, soybean meal and protein mixture rations was 19.9, 15.2, 23.6 and 20.3, respectively. The results indicated that soybean oil meal promoted the greatest nitrogen storage. However, the biological values of the protein of cottonseed meal, soybean oil meal and the protein mixture rations were not significantly different. The biological value of the peanut meal protein was significantly lower than that of the other three supplements. Briggs et al. (1946b), studying the same four supplements for steers, found no significant differences in nitrogen retention by the animals or in biological values of the proteins.

Lofgreen et al. (1947) studied the effect of urea, urea plus methionine, linseed meal and dried egg on nitrogen retention with lambs. Methionine added to urea increased nitrogen retention from 3.07 gm. per day to 3.77 gm. The lambs on linseed meal retained 3.73 gm. The striking result of this experiment was that the lambs on the dried egg ration retained 5.15 gm. nitrogen per day. They stated that their results suggest that under certain conditions the quality of protein fed in lamb rations may be of importance.

Most of the work thus far reviewed is consistent with the idea that nitrogenous compounds are changed to bacterial protein before being utilized by the host animal. Chalmers et al. (1954) presented data showing that nitrogen of casein is better utilized when administered directly into the duodenum of sheep than when administered into the rumen. They found that processing and state of division can influence the extent to which ammonia is produced from protein in the rumen. The formation of ammonia in the rumen from proteins may be an important factor in determining their nutritive value. In a second paper Chalmers and Synge (1954) found herring meal to be superior to casein in supporting nitrogen balance in sheep. Herring meal caused a less extensive formation of ammonia in the rumen than did the casein supplement. This was considered responsible for the difference in the value of the proteins. Annison et al. (1954) found the feeding of different protein supplements to sheep resulted in different concentrations of ammonia in the rumen.

Because of new developments in processing oil meals, attended by change in nutritive value (Miller and Morrison, 1944; Eagle et al., 1956), and because of wide use of these products in ruminant rations, it seemed worth-while to compare certain ones on the basis of growth promoting properties, digestibility and biological value of the protein.

EXPERIMENTAL

The oil meals selected for comparison were two samples of cottonseed meal, one of low and one of high nitrogen solubility, a sesame meal and a mixture of sesame meal and solvent processed soybean oil meal in which one-third of the protein was supplied by sesame meal and two-thirds by soybean oil meal. The percent protein content of the cottonseed meal of low nitrogen solubility, cottonseed meal of high nitrogen solubility, sesame meal and soybean oil meal was 41.2, 40.1, 40.6 and 46.4, respectively, on a dry matter basis.

Growth Trial

The supplements in amounts calculated to supply 67 percent of the total ration nitrogen were incorporated in rations shown in table 1. The rations were designed to furnish approximately 8 percent protein. Calcium carbonate and dicalcium phosphate were included to provide the same percentage of calcium and phosphorus in all rations. Vitamins A and D were supplied as Quadrex "10" Type IV.

The experimental animals were 24 newly-weaned wether lambs weighing about 55 lb. Several days before being put on the experimental rations, they were drenched with a preparation of phenothiazine and lead arsenate. The lambs were assigned at random to the four rations. They were kept in individual pens and fed all they would consume each day for a period of 56 days. Initial and final weights of the lambs were taken after 12-hour shrink periods. During the course of the trial weights were taken every two weeks.

Digestion and Nitrogen Balance Trials

Two digestion and nitrogen balance trials were conducted with the lambs at the end of the growth trial. There were 12 lambs in each trial, three lambs from each of four ration groups. Immediately preceding each trial the lambs were put on a common ration containing about 7 percent protein for a 12-day standardization period. They were then transferred to metabolism crates (Briggs and Gallup, 1949) and fed a constant amount (680 gm.) of their respective rations for successive 7-day preliminary and 10-day collection periods. In the interval between the growth trial and the standardization period of the second trial, the lambs were continued on the initial rations. The weight record for the lambs during the digestion trial is given in appendix table IV.

TABLE 1. CONSTITUENTS OF RATIONS FED TO LAMBS IN GROWTH TRIAL

Constituents (%)	Rations			
	CSM-LNS	CSM-HNS	SM	SM-SBOM
Cottonseed hulls	50.0	50.0	50.0	50.0
Cottonseed meal -LNS	13.3	-	-	-
Cottonseed meal -HNS	-	13.6	-	-
Sesame meal	-	-	13.5	4.4
Soybean oil meal	-	-	-	7.9
Cerelose	15.3	15.0	15.7	16.4
Cane molasses	20.0	20.0	20.0	20.0
Corn oil	0.2	0.2	0.2	0.2
NaCl	0.5	0.5	0.5	0.5
$CaCO_3$	0.6	0.6	-	-
$CaHPO_4$	-	-	-	0.5
Vitamin A-D	0.1	0.1	0.1	0.1

The rations in the first trial were formulated like those fed in the growth trial; however, corn oil was omitted. The phosphorus content of the sesame meal ration was increased by the addition of 0.2 percent monosodium phosphate and the calcium and phosphorus of the other rations adjusted with dicalcium phosphate and monosodium phosphate to the same level as in that ration. The rations in trial 2 were formulated like those in trial 1 except that corn oil was included (less than 0.7%) to adjust fat levels to that of the sesame meal ration. The chemical composition of the rations is shown in table 2. Through error, the final protein content of the sesame meal ration, 9.8 percent, was higher than that of the other rations which fell between 8.8 and 9.3 percent on a dry matter basis.

TABLE 2. AVERAGE PERCENTAGE COMPOSITION OF RATIONS FED TO LAMBS IN DIGESTION AND NITROGEN BALANCE TRIALS (DRY MATTER BASIS)

Rations	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
Trial 1					
Cottonseed meal -LNS	94.6	9.0	1.0	26.8	57.7
Cottonseed meal -HNS	94.3	8.8	0.8	26.9	57.8
Sesame meal	94.3	9.8	1.5	25.5	57.5
Sesame & soybean oil meal	94.1	9.3	1.0	25.8	58.0
Trial 2					
Cottonseed meal -LNS	94.6	8.7	1.5	24.0	60.8
Cottonseed meal -HNS	94.8	8.7	1.5	23.8	61.9
Sesame meal	94.6	9.6	1.4	23.2	60.4
Sesame & soybean oil meal	94.7	9.0	1.8	22.9	61.1

In both trials the lambs were fed equal amounts of ration twice daily. Water was always available. Feces were collected once daily and the total daily collection dried in a forced air oven at approximately 70° C. The total collection for each lamb was allowed to equilibrate, mixed and sampled for analysis. The urine was collected in glass jars containing HCl and daily aliquots (5 percent) were stored under refrigeration until sampled for chemical analysis. Chemical analyses were made according to the Methods of Analyses of the Association of Official Agricultural Chemists (1950). Results were tested for significance by analysis of variance as described by Snedecor (1946).

RESULTS AND DISCUSSION

The results of the growth trial are shown in the first part of table 3. The individual observations for the growth trial are shown in appendix table I. Lambs fed rations containing cottonseed meal of low and high nitrogen solubility made average daily gains of 0.26 and 0.30 lb. per day, as compared to 0.34 and 0.36 lb. for those fed the sesame meal and the sesame-soybean oil meal combination, respectively. Statistical analyses showed the above values not to be significantly different. In terms of feed efficiency and protein efficiency ratios, the cottonseed meal rations were inferior ($P < 0.05$) to the sesame meal and sesame-soybean oil meal combination rations. The trend in the growth trial was in favor of the cottonseed meal of high nitrogen solubility over the one of low nitrogen solubility.

Digestibility of nutrients as shown in the middle of table 3 was lower for the cottonseed meal rations than for sesame meal and sesame-soybean oil meal combination, the differences in digestibility of protein and of nitrogen-free extract in this comparison being highly significant ($P < 0.01$). Differences between the two cottonseed meals or between the two rations containing sesame meal failed to show significance or to establish a trend consistent with the results of the growth trial. Digestion coefficients obtained with individual lambs are given in appendix table II.

The average nitrogen balance data are shown in the last part of table 3, and the individual observations are shown in appendix table III.

TABLE 3. GROWTH, DIGESTIBILITY, AND NITROGEN BALANCE DATA OBTAINED WITH LAMBS FED DIFFERENT PROTEIN SUPPLEMENTS

Criteria	Response of lambs to rations containing			
	Cottonseed meal -LNS	Cottonseed meal -HNS	Sesame meal	Sesame-soybean oil meal
Growth trial				
Feed intake, lb.	3.43	3.75	3.47	3.77
Gain, lb.	0.26	0.30	0.34	0.36
Feed per lb. gain, lb.	13.90	12.58	10.32	10.65
Protein efficiency ratio[a]	0.98	1.04	1.25	1.23
Digestion trials[b]				
Dry matter intake, gm.	589	589	589	587
Digestibility (%)				
Organic matter	58.4	55.7	62.0	62.2
Protein	29.0	27.6	36.6	37.5
Ether extract	78.3	61.5	82.7	67.9
Crude fiber	42.6	40.5	44.6	46.5
N-free extract	69.2	66.8	72.9	72.1
Nitrogen balance[b]				
Nitrogen intake, gm.	8.3	8.2	9.2	8.6
Nitrogen in feces, gm.	5.9	6.0	5.8	5.4
Nitrogen in urine, gm.	1.9	1.9	2.1	2.5
Nitrogen retained, gm.	0.5	0.3	1.3	0.7
As percent of intake	6.3	4.4	14.1	8.6
As percent of digested	20.2	15.5	36.5	23.0

[a] Gain per unit of protein intake.

[b] Because of feed refusals, the number of lambs on each ration in the above order was six, five, four and five, respectively.

The nitrogen balance data afford further evidence of the superiority of the rations containing sesame meal or sesame-soybean oil meal combination over the cottonseed meals. Low nitrogen retention, 6.3 and 4.4 percent of intake, by lambs on the cottonseed meal rations resulted from high excretion of nitrogen in the feces. Fecal nitrogen excretion on the other two rations were less despite higher nitrogen intakes, and 14.1 and 8.6 percent of the total intake was retained. These differences approached significance. Expressing the average nitrogen retention as a percent of the digested nitrogen, to allow for differences in digestibility, did not change the order of results.

It is evident from a consideration of all the data that the cottonseed meal rations were inferior in nutritive value to the rations containing sesame or the 1:2 sesame-soybean oil meal combination. The results point toward a difference between the supplements in quality of protein and might be so interpreted. However in the comparison of the two cottonseed meals, differences in nutritive value were not of sufficient magnitude to relate them with confidence to a difference in nitrogen solubility or protein quality as has been done with non-ruminants (Lyman _et al._, 1953). Further, in the comparison of the sesame meal ration and the sesame-soybean oil meal combination, differences were too small relative to individual variation to supply evidence of a difference in protein quality, although according to the data of Almquist (1948) a difference in quality exists in favor of the combination.

Thus, the reason for the marked difference between the cottonseed meal rations and the other two rations in digestibility and in animal response is not obvious and may be related to dietary factors other than protein quality, _per se_. As a possible contributing factor the cottonseed meals were higher than the other meals in crude fiber, a natural constituent of low nutritive value that affects digestibility of other nutrients, particularly of protein, in different ways. Quantitative differences between the rations in crude fiber were only 1 percent. Apparently fat differences were not involved since equalization of fat in the different rations by the addition of less than 0.7 percent corn oil in trial 2 did not alter the results. Adequate amounts of the major minerals such as salt, calcium and phosphorus were present and other common mineral elements were provided by the molasses in the four rations; there remained, very likely, a small difference in mineral distribution.

SUMMARY

Cottonseed meal of low and high nitrogen solubility, sesame meal and a sesame-soybean mixture (1:2) were compared as protein supplements for lambs in growth and nitrogen balance trials. All measurements of nitrogen utilization and also feed efficiency and digestibility of non-nitrogenous nutrients, favored the sesame meal and sesame-soybean oil meal combination over the two cottonseed meals. Low digestibility of the nitrogen characterized the cottonseed meal rations.

Differences in the nutritive value between the two types of cottonseed meal, despite differences in solubility, were not statistically significant.

PART II

NUTRITIVE VALUE OF COTTONSEED MEAL, SESAME MEAL AND SOYBEAN OIL MEAL FED AT THREE PROTEIN LEVELS

INTRODUCTION

The results of the growth, digestion and nitrogen balance trials of Part I of this study indicated cottonseed meal to be inferior to sesame meal or a combination of soybean oil meal and sesame meal as a protein supplement for lambs. It is possible for differences to exist between protein supplements at one level of intake and for these differences not to be apparent at another (Mitchell, 1924d). For this reason a series of trials were initiated to test the three supplements at different levels of intake.

It has been shown by Melnick and Cowgill (1937), Harris and Mitchell (1941) and Allison and Anderson (1945) that a linear relationship exists between nitrogen balance and nitrogen intake or absorbed nitrogen in the region of nitrogen equilibrum. In the following discussion absorbed nitrogen designates apparent digested nitrogen. The relationship between nitrogen balance (NB) and absorbed nitrogen (AN) can be expressed as $NB = K(AN) - NE_0$, where K is the slope of the line and NE_0 is the excretion of nitrogen when the nitrogen intake is zero (Allison and Anderson, 1945). The slope of the line (K) has been called the nitrogen balance index of the dietary protein. The index is a function of the fraction of nitrogen retained in the body of the animal. It is more specifically the rate of change of nitrogen balance with respect to absorbed nitrogen (Allison, 1951). The relationship between nitrogen balance and nitrogen intake or absorbed nitrogen permits the extrapolation of a line to obtain estimates of protein requirements and to obtain a relative measure of the nutritive value of a protein.

EXPERIMENTAL

The percent protein content on a dry matter basis of the soybean oil meal, sesame meal and cottonseed meal used in this series of trials was 51.1, 49.6 and 43.1, respectively. The chemical composition of the protein supplements is shown in table 4. The soybean oil meal was a solvent process product and the cottonseed meal was a hydraulic press product; both of the meals were purchased on the local market. The sesame meal was purchased from California Milling Corporation, Los Angeles, California. The nutritive value of these specific supplements was not known.

TABLE 4. PERCENTAGE COMPOSITION OF PROTEIN SUPPLEMENTS AND CELLULOSE (DRY-MATTER BASIS)

Supplement	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
Soybean oil meal	93.0	51.1	1.4	5.3	35.2
Sesame meal	87.8	49.6	7.2	5.0	26.0
Cottonseed meal	93.5	43.1	4.0	13.6	32.8
Cellulose (Solka floc)	100.0	-	-	84.0	16.0

The supplements were compared at three levels of intake in semi-purified diets in which they supplied 90 to 95 percent of the total nitrogen in the diet. Protein levels were approximately 4, 6 and 8 percent. The 4 percent protein rations were compared in trials H4 and H5, the 6 percent protein rations in trials H6 and H7 and the 8 percent protein rations in trials H8 and H9. Two groups of 12 lambs were used as the experimental animals. In each trial there were 4 lambs on each supplement, making a total of 8 lambs on each level of each supplement. The lambs of the first group were in metabolism crates (Briggs and Gallup, 1949) for both the 10-day preliminary period and the 7-day collection period. The lambs of the second group were in the metabolism crates during only the collection period. They were fed in individual feeders during the preliminary period. Following each collection period the lambs were given a 10-day standardization period in which they were fed a 9 percent protein ration. At the beginning of each trial the lambs were allotted at random to the different treatments. Approximately 80 days elapsed from the time the lambs were started until the end of the last collection period. The weight record of the lambs is given in appendix table V.

The constituents of the rations are shown in table 5. It was necessary to replace part of the cellulose (10 percent) with cottonseed hulls in order to maintain desired feed consumption. The constant part of each ration, in gm., was cellulose (Solka floc), 180; cottonseed hulls, 60; mineral mixture, 30; corn oil, 30 and vitamin A and D, 1. The protein supplement in each ration varied according to its protein content. A mixture of equal parts of starch and cerelose was added to bring the total to 600 gm. The composition of the mineral mixture which is shown at the bottom of table 5 is similar to the mixture of Thomas et al. (1951). The chemical composition of the rations is given in table 6.

Feces and urine were collected and sampled as described in Part I. The chemical analyses were made according to standard methods of the Association of Official Agricultural Chemists (1950). The regression analyses and analysis of variance were conducted as described by Snedecor (1946).

TABLE 5. COMPOSITION OF RATIONS FED TO LAMBS IN NITROGEN BALANCE TRIALS

Ingredient (gm.)[a]	4% Protein ration			6% Protein ration			8% Protein ration		
	Soybean oil meal	Sesame meal	Cottonseed meal	Soybean oil meal	Sesame meal	Cottonseed meal	Soybean oil meal	Sesame meal	Cottonseed meal
Cellulose	180	180	180	180	180	180	180	180	180
Cottonseed hulls	60	60	60	60	60	60	60	60	60
Mineral mixture[b]	30	30	30	30	30	30	30	30	30
Corn oil	30	30	30	30	30	30	30	30	30
Vitamin A and D[c]	1	1	1	1	1	1	1	1	1
Soybean oil meal	46	-	-	72	-	-	97	-	-
Sesame meal	-	46	-	-	72	-	-	97	-
Cottonseed meal	-	-	54	-	-	84	-	-	113
Cerelose	126.5	126.5	122.5	113.5	113.5	107.5	101	101	93
Starch	126.5	126.5	122.5	113.5	113.5	107.5	101	101	93

[a] Each ration contained 12 mg. of d-alpha-tocopherol acetate

[b] Composition of mineral mixture (gm.): NaCl, 378; KH_2PO_4, 668; $CaHPO_4 \cdot 2H_2O$, 746; $MgSO_4$, 207; $CaSO_4 \cdot 2H_2O$, 875; $CaCO_3$, 63.3; $FeSO_4$, 16.2; KI, 1.7; $ZnSO_4$, 0.6; $CuSO_4 \cdot 5H_2O$, 0.7; $CoSO_4 \cdot H_2O$, 0.4; CaF_2, 0.5; $MnSO_4 \cdot H_2O$, 3.0

[c] Feed supplement containing 10,000 units vitamin A and 1250 units vitamin D per gram.

TABLE 6. AVERAGE PERCENTAGE COMPOSITION OF RATIONS FED TO LAMBS (DRY MATTER BASIS)

Ration	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
4% Protein					
Soybean oil meal	94.9	4.4	6.0	30.3	54.2
Sesame meal	94.5	4.4	6.5	30.2	53.4
Cottonseed meal	95.0	4.4	6.1	31.0	53.5
6% Protein					
Soybean oil meal	94.6	6.5	6.1	30.5	51.5
Sesame meal	94.0	6.3	6.6	30.3	50.8
Cottonseed meal	94.4	6.5	6.4	31.7	49.8
8% Protein					
Soybean oil meal	94.4	9.0	6.0	30.6	48.8
Sesame meal	93.6	8.3	7.0	30.5	47.8
Cottonseed meal	94.4	8.5	6.9	32.1	46.9

RESULTS AND DISCUSSION

The average digestion coefficients and nitrogen balance data are given in table 7. Digestion coefficients obtained with individual lambs on the soybean oil meal, sesame meal and cottonseed meal rations are shown in appendix tables VI, VII and VIII, respectively. Nitrogen retention for individual lambs is given in appendix tables IX, X and XI. If a lamb refused feed, he was removed from consideration in the results. The number of observations per treatment is given at the top of table 7.

As the level of protein in the ration increased, generally the digestibility of all nutrients increased. An increase in digestibility of nutrients would be expected over the range of protein studied. Differences between the different supplements in organic matter digestibility were not statistically significant. The digestibility of protein was significantly ($P < 0.01$) higher in the soybean oil meal and sesame meal rations than in the cottonseed meal ration. These differences in protein digestibility were evident at the three levels studied. The magnitude of the differences ranged from 6 to 14 percentage units. A significant ($P < 0.01$) interaction in protein digestibility occurred between levels of supplement and source. This was the result of soybean oil meal protein being lower in digestibility than sesame meal protein in the 4- and 6-percent protein rations and higher in digestibility in the 8-percent protein ration.

TABLE 7. DIGESTIBILITY AND NITROGEN BALANCE DATA OBTAINED WITH LAMBS FED DIFFERENT PROTEIN SUPPLEMENTS AT DIFFERENT LEVELS

Items compared	4% Protein ration			6% Protein ration			8% Protein ration		
	Soybean oil meal	Sesame meal	Cottonseed meal	Soybean oil meal	Sesame meal	Cottonseed meal	Soybean oil meal	Sesame meal	Cottonseed meal
No. of lambs	7	7	6	8	6	5	8	7	8
Dry matter intake (gm.)	558.8	559.4	560.4	561.3	563.2	560.0	560.3	561.2	561.0
Digestibility (%)									
Organic matter	60.1	58.5	62.4	71.4	68.1	62.1	78.3	76.1	74.0
Protein	27.3	29.9	20.8	38.7	40.1	32.3	58.3	52.4	43.7
Ether extract	85.7	89.8	87.2	88.1	86.3	91.7	88.7	92.8	93.1
Crude fiber	29.4	24.6	33.5	59.5	52.2	41.4	72.8	70.0	68.8
N-free extract	77.1	76.3	76.1	80.5	78.6	75.4	84.0	81.7	80.4
Nitrogen balance (gm.)									
Nitrogen intake	3.95	3.96	3.91	5.82	5.67	5.82	8.10	7.47	7.61
Nitrogen in feces	2.85	2.77	3.09	3.56	3.39	3.93	3.38	3.56	4.29
Nitrogen in urine	1.88	1.82	1.71	2.45	2.27	2.18	3.44	2.48	2.15
Nitrogen retention	-0.81	-0.63	-0.89	-0.20	0.01	-0.29	1.28	1.44	1.18
Percent nitrogen retained	-20.5	-15.9	-22.8	-3.4	0.2	-5.0	15.8	19.3	15.5

Nitrogen intake on the different supplements at each calculated level of protein was approximately the same, except at the 8-percent protein level the nitrogen intake for the lambs on the soybean oil meal ration was about 0.5 gm. higher than for those on the sesame or cottonseed meal rations. The nitrogen retention for the lambs fed cottonseed meal rations was lowest, soybean oil meal rations intermediate and sesame meal rations the highest at all levels studied; however, these differences were not statistically significant. It should be pointed out that the lambs fed soybean oil meal excreted a higher amount of nitrogen in the urine than the lambs fed either sesame or cottonseed meal. The lambs fed cottonseed meal excreted the smallest amount of urinary nitrogen (see table 7).

Regression analyses of nitrogen retention on nitrogen intake for the three supplements are given in table 8. The relationship between nitrogen retention and nitrogen intake is shown in figure 1. There was a high correlation between nitrogen intake and nitrogen retention, the correlation coefficients (r) for soybean oil meal, sesame meal and cottonseed meal being 0.86, 0.89 and 0.88, respectively. The regression coefficients (b) for the supplements ranged from 0.51 to 0.59 and the range of their confidence intervals would indicate that they could easily be estimates of the same parameter (see bottom of table 8).

In table 9 the regression analyses of nitrogen balance on apparent absorbed nitrogen are given. The relationship between nitrogen balance and absorbed nitrogen for the three supplements is shown in figure 2. The correlation coefficients for this relationship for soybean oil meal, sesame meal and cottonseed meal are 0.93, 0.93 and 0.95, respectively. The regression coefficient (nitrogen balance index) for soybean oil meal is 0.60 as compared to 0.77 for sesame meal and 0.85

TABLE 8. STATISTICAL DATA

THE REGRESSION OF NITROGEN RETENTION
ON NITROGEN INTAKE

Quantity	Soybean oil meal	Sesame meal	Cottonseed meal
Sx^2	65.88	43.17	47.22
Sy^2	22.98	19.16	19.53
Sxy	33.54	25.50	26.75
Slope b	0.51	0.59	0.57
x(mean of N intake)	6.04	5.70	5.97
y(mean of N retention)	0.13	0.29	0.14
Regression equation	Y=0.51X-2.94	Y=0.59X-3.08	Y=0.57-3.24
4% Protein ration			
Expected Y	-0.94	-0.73	-1.03
Observed Y	-0.81	-0.63	-0.89
6% Protein ration			
Expected Y	0.02	0.25	0.05
Observed Y	-0.20	0.01	-0.29
8% Protein ration			
Expected Y	1.18	1.34	1.07
Observed Y	1.28	1.44	1.18
$Sdy \cdot x^2$	5.90	4.10	4.38
$sy \cdot x^2$	0.28	0.23	0.26
$sy \cdot x$	0.53	0.48	0.51
sb	0.065	0.073	0.074
r	0.86	0.89	0.88
Confidence limits of b at 5 percent level			
l_1	0.64	0.74	0.73
l_2	0.38	0.44	0.41

FIGURE 1. REGRESSION OF NITROGEN RETENTION ON NITROGEN INTAKE

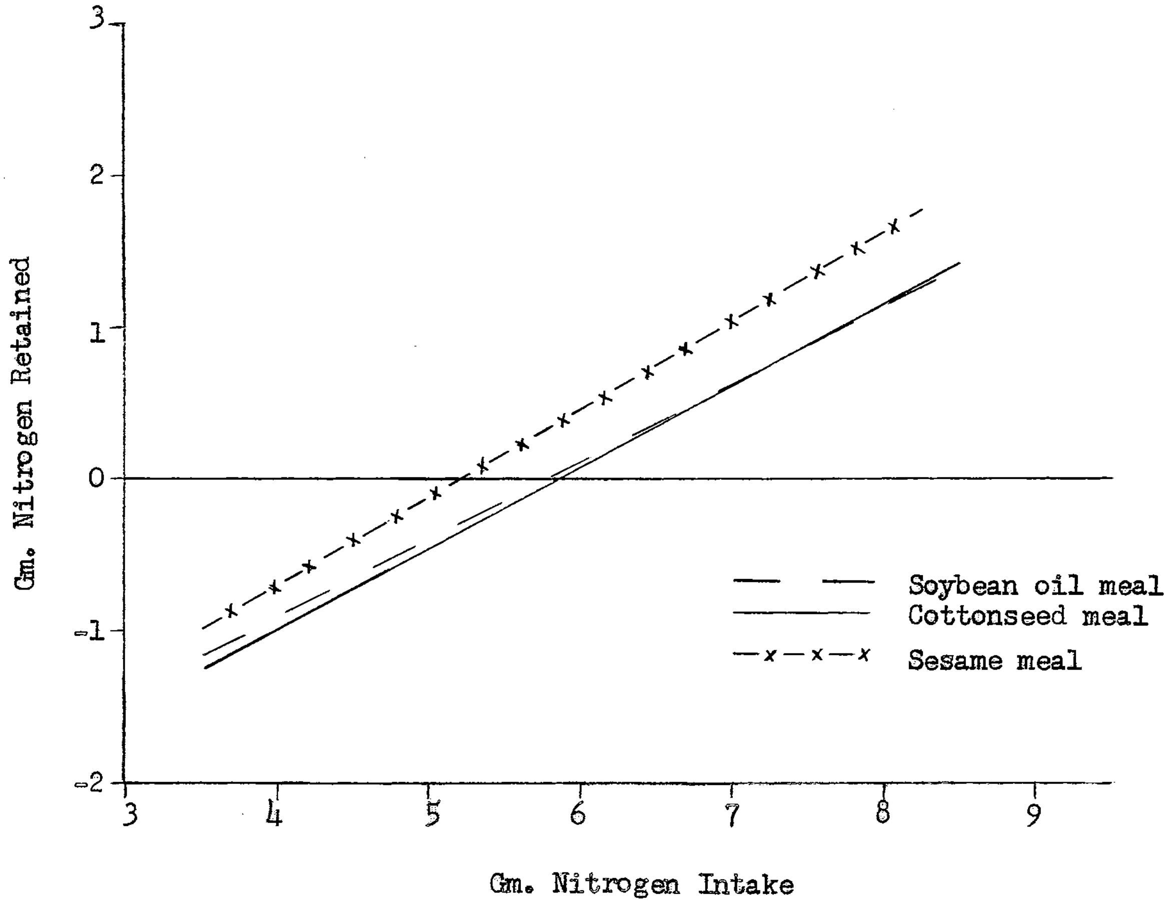
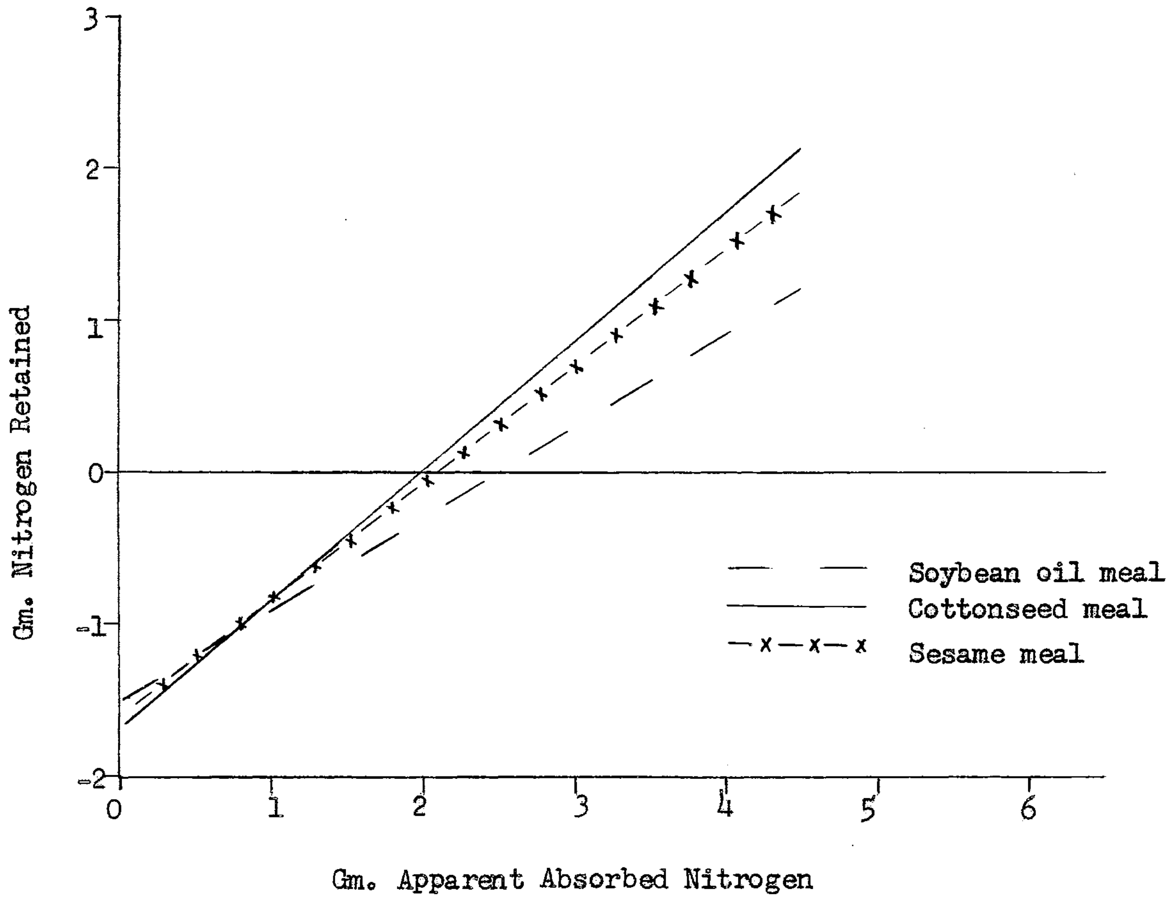


TABLE 9. STATISTICAL DATA

THE REGRESSION OF NITROGEN RETENTION ON APPARENT ABSORBED NITROGEN

Quantity	Soybean oil meal	Sesame meal	Cottonseed meal
Sx^2	55.77	27.81	24.34
Sy^2	22.98	19.16	19.53
Sxy	33.43	21.51	20.63
Slope b	0.60	0.77	0.85
x(mean of N absorbed)	2.75	2.47	2.16
y(mean of N retention)	0.13	0.29	0.14
Regression equation	Y=0.60X-1.52	Y=0.77X-1.61	Y=0.85X-1.69
4% Protein ration			
Expected Y	-0.88	-0.69	-0.99
Observed Y	-0.81	-0.63	-0.89
6% Protein ration			
Expected Y	-0.17	0.15	-0.08
Observed Y	-0.20	0.01	-0.29
8% Protein ration			
Expected Y	1.31	1.42	1.14
Observed Y	1.28	1.44	1.18
$Sdy \cdot x^2$	2.94	2.52	2.05
$sy \cdot x^2$	0.14	0.14	0.12
$sy \cdot x$	0.37	0.37	0.35
sb	0.050	0.071	0.070
r	0.93	0.93	0.95
Confidence limits of b at 5 percent level			
l_1	0.70	0.92	1.00
l_2	0.50	0.62	0.70

FIGURE 2. REGRESSION OF NITROGEN RETENTION
ON APPARENT ABSORBED NITROGEN



for cottonseed meal. These values represent the change in retention of nitrogen per unit intake of digested nitrogen. The confidence limits of the regression coefficients are given at the bottom of table 9. There is a significant ($P < 0.01$) difference between the nitrogen balance indices for soybean oil meal and cottonseed meal using the test as described by Snedecor (1946) for regression coefficients. Nitrogen balance index as used in the present study is an estimate of the biological value of a protein but does not necessarily equal it. If it is assumed that metabolic and endogenous nitrogen are constant, the nitrogen balance index represents the fraction of absorbed food nitrogen retained (which would represent the biological value as described by Allison), otherwise it is simply the rate of change of nitrogen balance with respect to absorbed nitrogen. It has been shown with dogs that the indices tend to increase when the protein stores of the animal are depleted (Allison et al., 1946). The correlation between digestibility of protein and biological value was concluded to be negative by Mitchell (1942, 1943). Swanson and Herman (1943) found that biological values were highly correlated with the nutritive ratio of the ration. In this experiment for the 8-percent protein ration the nutritive ratio of cottonseed meal ration was 1:20 as compared to 1:17 for the sesame meal ration and 1:14 for the soybean oil meal ration. This would have tended to give cottonseed meal the highest nitrogen balance index (biological value). Mitchell (1924b) presented data showing that biological values were higher at low levels of protein intake than at high levels. The nitrogen balance index for cottonseed meal was higher than that for soybean oil meal and would indicate that the biological value of cottonseed meal protein is higher under the conditions of this experiment. The most comparable values of the nutritive value of proteins should be obtained when they are used to satisfy the same fraction of the total requirement for nitrogen, rather than some fixed level (Mitchell, 1943). The results of this experiment tend to confirm those of other investigators (Miller and Morrison, 1942 and Johnson et al., 1942) that for sheep there are no marked differences between protein supplements. The low digestibility of cottonseed meal protein was offset by efficient utilization of the digested nitrogen.

The results of this study confirm the low digestibility of cottonseed meal protein as compared to soybean oil meal or sesame meal protein. Briggs et al. (1946a), in trials with lambs on prairie hay supplemented with cottonseed meal or soybean oil meal, found cottonseed meal protein to be lower in digestibility than soybean oil meal protein. As suggested earlier in Part I, the high amount of crude fiber in cottonseed meal may account for the lower digestibility. In this study cottonseed meal contained 13.6 percent crude fiber as compared to 5.3 and 5.0 for soybean oil meal and sesame meal. The protein in cottonseed hulls is indigestible (Morrison, 1956). This indigestible protein coupled with an increase in metabolic nitrogen from the fibrous portion of the ration (Mitchell, 1926) could account for lower digestibility. It should not be overlooked, however, that low digestibility may be a characteristic of the protein itself.

SUMMARY

Six digestion and nitrogen balance trials were conducted with 24 lambs to compare cottonseed meal, sesame meal and soybean oil meal as protein supplements in semi-purified diets. Three levels of protein, 4, 6 and 8 percent, were used. Cottonseed meal protein was significantly lower in digestibility than sesame meal or soybean oil meal protein at the three levels studied. This lower digestibility of protein resulted in a slightly but not significantly lower nitrogen retention. A regression of nitrogen retention on nitrogen intake indicated the supplements to be the same in nutritive value for lambs. The nitrogen balance index for cottonseed meal was 0.85 as compared to 0.77 for sesame meal and 0.60 for soybean oil meal. There was a significant ($P < 0.01$) difference between cottonseed meal and soybean oil meal in this measurement which would indicate a greater retention per unit of digested cottonseed meal nitrogen than of digested soybean oil meal nitrogen.

PART III

EFFECT OF COTTONSEED HULLS ON DIGESTION AND UTILIZATION OF PROTEIN IN COTTONSEED MEAL AND SOYBEAN OIL MEAL

INTRODUCTION

In the production of commercial cottonseed meal, cottonseed hulls are used to lower the protein content of an essentially hull-free meal to a desired protein level. The hulls are high in fiber and low in protein. It has been suggested that the presence of hulls in cottonseed meal accounts in part for the difference in nutritive value between cottonseed meal and certain other oil meals. The purpose of this investigation was to study the effect of added cottonseed hulls on the digestibility of a hull-free cottonseed meal and of soybean oil meal. At the same time the investigation offered an opportunity to compare a specially prepared cottonseed meal (hull-free) with commercial soybean oil meal.

EXPERIMENTAL

Samples of hull-free cottonseed meal and of cottonseed hulls were obtained from Traders Oil Meal Company through the courtesy of the National Cottonseed Products Association, Inc. Ordinarily sufficient cottonseed hulls are added to the meal to adjust the protein to desired levels (40-43%). The soybean oil meal was a solvent process product obtained on the local market. The chemical composition of these products is given in table 10. The hull-free cottonseed meal and soybean oil meal contained 59.9 and 52.9 percent protein, respectively, on a dry matter basis. The hull-free cottonseed meal contained 2.8 percent crude fiber as compared to 5.8 percent crude fiber in soybean oil meal.

TABLE 10. PERCENTAGE COMPOSITION OF FEEDS (DRY MATTER BASIS)

Feeds	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
Prairie hay	93.7	4.3	2.1	34.6	52.7
Cottonseed meal[a]	93.3	59.9	4.1	2.8	26.5
Soybean oil meal	93.1	52.9	1.2	5.8	33.2
Cottonseed hulls	97.2	4.6	1.2	40.4	51.0

[a] Hull-free sample

The rations were designed so that the effect of cottonseed hulls on the digestibility of both cottonseed meal and soybean oil meal could be studied. The components of the rations are given in table 11. Ration 1, in gm., was composed of prairie hay, 500; cottonseed meal (hull-free), 88; $CaHPO_4$, 14; NaCl, 5; and vitamin A and D, 1. In ration 2, 38 gm. of cottonseed meal replaced 2 gm. of cottonseed meal. This replacement has the effect of reducing the protein content of the cottonseed meal from 59.9 to 41 percent. Thus ration 2 was similar to one that might be made up with a commercial grade of cottonseed meal. Ration 3 was similar to ration 1 except that it contained 108 gm. of soybean oil meal in place of the cottonseed meal. Ration 4 was made similar to ration 2 by including 38 gm. of cottonseed hulls. The hulls replaced 4 gm. of soybean oil meal. The chemical composition of the rations is given at the bottom of table 11.

TABLE 11. INGREDIENTS AND CHEMICAL COMPOSITION OF RATIONS

	Hull-free cottonseed meal		Soybean oil meal	
Ingredients (gm.)	No hulls	Added hulls	No hulls	Added hulls
Prairie hay	500	500	500	500
Cottonseed meal[a]	88	86	-	-
Soybean oil meal	-	-	108	104
Cottonseed hulls	-	38	-	38
$CaHPO_4$	14	14	14	14
Salt	5	5	5	5
Vitamin A and D[b]	1	1	1	1
Total	608	644	628	662
Dry matter (%)	95.6	95.5	95.5	95.4
Composition dry matter basis (%)				
Organic matter	90.5	91.0	90.7	91.0
Protein	12.2	11.6	12.5	11.8
Ether extract	2.3	2.3	1.9	1.8
Crude fiber	28.8	29.6	28.6	29.4
N-free extract	47.2	47.5	47.7	48.0

[a] Hull-free sample

[b] Contained 10,000 units of vitamin A and 1,250 units of vitamin D per gm.

Two groups of 12 wether lambs each were used as the experimental animals. The weight record for the lambs is given in appendix table XII. The first group was placed in metabolism stalls (Briggs and Gallup, 1949) for the 10-day preliminary and 10-day collection period. The lambs of the second group were handled so that 9 days of the preliminary period was conducted in individual stanchions. They were then moved into the metabolism stalls for 1 day of the preliminary period and the 10-day collection period. The treatments were randomly assigned to the lambs. There was a total of 6 lambs per treatment.

The prairie hay was sorted before feeding in order to remove most of the weeds and large stems. The hay was ground in a hammer mill through a one-half inch screen. The lambs were fed twice daily, receiving one-half of their daily feed at each feeding. Water was available at all times. Feces and urine were collected and handled as described in Part I. The chemical analyses were made according to the Methods of Analysis of the Association of Official Chemists (1950). Results were tested for significance by analysis of variance as described by Snedecor (1946). In cases of significance, orthogonal comparisons were used to test for individual effects.

RESULTS AND DISCUSSION

The lambs readily consumed the feed offered them for the 20-day period. The average digestion coefficients and nitrogen balance data are given in table 12. The individual values for digestion coefficients and nitrogen retention are given in appendix tables XIII and XIV.

TABLE 12. DIGESTIBILITY AND NITROGEN BALANCE DATA

Items compared	Hull-free cottonseed meal: No hulls	Hull-free cottonseed meal: Added hulls	Soybean oil meal: No hulls	Soybean oil meal: Added hulls
Dry matter intake (gm.)	581.3	615.1	599.7	631.6
Digestibility (%)				
Organic matter	61.5	60.2	63.0	62.3
Protein	64.7	61.3	69.2	66.1
Ether extract	47.4	46.7	37.0	31.0
Crude fiber	65.7	63.8	66.5	65.3
N-free extract	58.7	58.3	60.4	61.3
Nitrogen balance (gm.)				
Nitrogen intake	11.38	11.45	12.00	11.94
Nitrogen in feces	4.02	4.43	3.70	4.04
Nitrogen in urine	5.38	5.30	6.06	5.95
Nitrogen retention	1.98	1.72	2.24	1.95
Nitrogen intake retained (%)	17.4	15.0	18.7	16.3

The digestibility of organic matter in the rations containing soybean oil meal was significantly ($P < 0.05$) higher than that in the rations containing cottonseed meal. The organic matter digestion coefficients for rations 1, 2, 3 and 4 were 61.5, 60.2, 63.0 and 62.3, respectively. The addition of cottonseed hulls to each ration tended to reduce ($P < 0.25$) organic matter digestibility. The digestibility of protein was significantly ($P < 0.01$) higher in the soybean oil meal rations than in the cottonseed meal rations. The addition of cottonseed hulls reduced ($P < 0.01$) protein digestibility in both rations by about 3 percentage units. Differences between rations in crude fiber digestibility were small. The addition of 38 gm. of cottonseed hulls increased the crude fiber content of the rations only 0.8 percent. Such a small amount added would not be expected to affect the digestibility of total fiber in the ration. The digestibility of nitrogen-free extract was significantly ($P < 0.01$) higher in the soybean oil meal rations than in the cottonseed meal rations.

The level of probability for a difference among all rations in nitrogen retention was 0.25. Percent nitrogen intake retained by the lambs on rations 1, 2, 3 and 4 was 17.4, 15.0, 18.7 and 16.3, respectively. Although the lambs on the soybean oil meal had higher nitrogen intakes than those on cottonseed meal, they excreted less nitrogen in the feces and more nitrogen in the urine. There was a trend for the lambs fed soybean oil meal to retain more nitrogen than those fed cottonseed meal. Cottonseed hulls added to both rations decreased nitrogen retention but not significantly. This decrease in retention was apparently due to decreased digestibility of ration nitrogen.

On the basis of fecal metabolic nitrogen being equal to 0.55 gm. per 100 gm. dry matter intake (Harris and Mitchell, 1941) the dry matter contained in the added cottonseed hulls would be expected to increase the fecal excretion of metabolic nitrogen by 0.20 gm. When cottonseed hulls were added to cottonseed meal and soybean oil meal rations, nitrogen in the feces increased by 0.42 and 0.34 gm., respectively. The amount of nitrogen contained in the 38 gm. of cottonseed hulls was 0.27 gm. If the nitrogen in the cottonseed hulls were undigested, this undigested nitrogen and metabolic nitrogen would account for slightly more than the increase in fecal nitrogen when cottonseed hulls were added to the rations. It seems probable that some of the nitrogen in cottonseed hulls was digested.

The results of this experiment would indicate that cottonseed meal protein itself is lower in digestibility than soybean oil meal protein. The crude protein digestion coefficients were approximately 5 percentage units lower for the cottonseed meal rations than for the soybean oil meal rations ($P<0.01$). It is possible that the method of processing lowered protein digestibility by the lambs. The results of Part I would indicate that a difference between oil meals in nitrogen solubility was of little importance in lamb rations. The results of the present experiment indicate that hulls in commercial cottonseed meal lower the apparent digestibility of protein in the product.

SUMMARY

Twenty-four wether lambs were used to study the effect of small amounts of cottonseed hulls as found in commercial cottonseed meal on the digestibility of hull-free cottonseed meal and soybean oil meal. The two meals were fed as supplements to prairie hay. The addition of cottonseed hulls significantly reduced the digestibility of the protein in the rations. This decrease appears to be due to an increase in metabolic nitrogen and a low digestibility of cottonseed hull protein. Soybean oil meal protein was more digestible than cottonseed meal protein in the presence and absence of cottonseed hulls. The digestibility of organic matter and nitrogen-free extract was significantly higher in the soybean oil meal rations than in the cottonseed meal ration. The lambs fed soybean oil meal retained more nitrogen than those fed cottonseed meal whether or not the ration contained added hulls. The decrease in digestibility of protein due to cottonseed hulls was reflected in a lowered nitrogen retention.

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APPENDIX

TABLE I. DAILY GAINS, FEED INTAKE, FEED EFFICIENCY AND PROTEIN EFFICIENCY FOR LAMBS ON DIFFERENT PROTEIN SUPPLEMENTS

Ration	Lamb	Av. daily gain(lb.)	Av. daily intake(lb.)	Feed efficiency	Protein efficiency
Cottonseed meal low-N solubility	22	0.20	3.51	17.57	0.74
	05	0.19	3.54	18.66	0.67
	27	0.39	3.70	9.49	1.35
	5	0.20	2.94	14.73	0.88
	0	0.28	3.34	11.94	1.08
	3	0.32	3.53	11.04	1.16
Cottonseed meal high-N solubility	28	0.33	3.74	11.34	1.14
	06	0.36	4.50	12.51	1.02
	4	0.27	3.57	13.22	0.97
	03	0.30	3.81	12.69	1.03
	20	0.28	2.89	10.31	1.24
	2	0.26	4.01	15.41	0.84
Sesame meal	00	0.31	3.54	11.42	1.14
	9	0.36	3.59	9.96	1.24
	7	0.33	3.21	9.73	1.33
	26	0.28	3.00	10.72	1.20
	08	0.39	3.45	8.85	1.45
	02	0.36	4.04	11.22	1.14
Soybean - sesame meal	04	0.59	5.48	9.29	1.39
	23	0.32	3.10	9.69	1.34
	80	0.30	3.58	11.95	1.11
	25	0.32	3.33	10.40	1.24
	07	0.29	3.46	11.93	1.07

TABLE II. APPARENT DIGESTION COEFFICIENT FOR LAMBS FED DIFFERENT PROTEIN SUPPLEMENTS

Ration	Trial	Lamb	Digestion coefficients					
			Dry matter	Organic matter	Protein	Crude fiber	Ether extract	N-free extract
Cottonseed meal low-N solubility	1	03	52.3	52.0	22.3	35.1	74.6	64.1
	1	4	59.4	58.8	33.7	47.0	81.3	67.9
	1	08	62.3	62.8	32.5	45.3	71.2	71.5
	2	00	60.4	60.0	28.1	45.5	81.3	69.8
	2	27	60.5	60.7	26.9	44.7	81.3	71.4
	2	23	58.8	58.9	30.4	38.0	80.2	70.7
Cottonseed meal high-N solubility	1	8	57.6	57.0	27.2	46.4	69.6	66.3
	1	5	55.2	55.0	26.5	42.2	41.3	65.4
	1	26	53.9	53.2	27.6	39.0	43.5	63.8
	2	05	57.6	57.6	30.0	34.1	77.2	70.3
	2	28	55.8	55.5	26.6	41.8	76.1	68.2
Sesame meal	1	3	63.1	63.7	29.4	52.2	81.4	74.3
	1	25	62.9	63.0	41.0	48.1	82.5	72.9
	2	22	61.5	61.2	38.8	40.8	80.0	72.3
	2	20	60.5	60.3	37.3	37.2	87.0	72.3
Soybean - sesame meal	1	0	61.6	61.6	39.3	44.9	51.7	71.6
	1	06	62.2	61.8	40.1	47.6	70.7	71.5
	1	07	63.8	63.5	31.3	53.6	58.6	73.1
	2	6	59.2	59.2	36.0	41.9	76.9	68.8
	2	04	64.5	64.9	40.7	44.4	81.7	75.7

TABLE III. NITROGEN BALANCE DATA FOR LAMBS FED DIFFERENT PROTEIN SUPPLEMENTS

Ration	Trial	Lamb	N intake	N in feces	N in urine	N retained	N intake retained	Digested N retained
			gm.	gm.	gm.	gm.	%	%
Cottonseed meal low-N solubility	1	03	8.43	6.55	1.96	-0.08	-0.95	-4.26
	1	4	8.43	5.59	1.87	0.97	11.51	34.15
	1	08	8.43	5.69	2.16	0.58	6.88	21.17
	2	00	8.26	5.94	1.74	0.58	7.02	25.00
	2	23	8.26	5.75	1.74	0.77	9.32	30.68
	2	27	8.26	6.03	1.91	0.32	3.87	14.35
Cottonseed meal high-N solubility	1	8	8.23	5.98	1.98	0.27	3.28	12.00
	1	5	8.23	6.05	1.95	0.23	2.79	10.55
	1	26	8.23	5.96	1.91	0.36	4.37	15.86
	2	05	8.26	5.78	1.80	0.68	8.23	27.42
	2	28	8.26	6.06	1.94	0.26	3.15	11.82
Sesame meal	1	3	9.20	6.49	2.49	0.22	2.39	8.12
	1	25	9.20	5.43	1.98	1.79	19.46	47.48
	2	22	9.17	5.60	2.08	1.49	16.25	41.74
	2	20	9.17	5.74	1.76	1.67	18.21	48.69
Soybean-sesame meal	1	0	8.68	5.26	2.30	1.12	12.90	32.75
	1	06	8.68	5.20	2.42	1.06	12.21	30.46
	1	07	8.68	5.96	2.28	0.44	5.07	16.18
	2	06	8.57	5.48	1.96	1.13	13.19	36.57
	2	04	8.57	5.08	3.53	-0.04	-0.47	-1.15

TABLE IV. WEIGHT RECORD FOR LAMBS FED DIFFERENT PROTEIN SUPPLEMENTS

Trial I			Trial II		
Lamb	Initial weight 7/6/55	Final weight 7/23/55	Lamb	Initial weight 7/23/55	Final weight 8/7/55
03	59.5	59.5	6	70.0	70.0
3	69.5	70.0	00	72.0	70.5
4	66.0	68.0	22	68.0	68.0
8	68.5	68.0	27	80.5	80.0
0	59.0	60.0	04	86.0	83.5
5	63.0	60.5	05	67.0	68.0
26	67.5	65.0	28	77.0	77.5
08	64.0	65.0	20	66.0	67.0
25	70.5	67.5	23	68.5	68.5
06	68.5	67.0			
07	57.5	61.5			

TABLE V. WEIGHT RECORD FOR LAMBS FED SOYBEAN, SESAME AND COTTONSEED MEALS AT DIFFERENT LEVELS (LB.)

Lamb	Initial weight	Final weight	Initial weight	Final weight	Initial weight	Final weight
	Trial H4		Trial H6		Trial H8	
	3/17/56	4/9/56	4/19/56	5/5/56	5/15/56	5/29/56
1	66.0	61.0	64.5	68.0	71.0	71.0
2	62.0	*	57.5	57.5	61.5	63.5
3	80.5	71.0	76.5	75.0	80.0	80.0
4	71.0	64.0	68.5	*	72.5	72.5
5	72.0	64.0	67.0	69.0	69.5	73.0
6	69.5	*	65.5	63.0	67.5	68.0
7	62.5	*	65.0	67.5	67.5	68.5
8	59.5	54.0	54.0	58.0	58.5	60.5
9	61.5	51.5	54.0	57.0	60.0	61.5
10	63.0	*	57.5	58.5	62.5	64.5
11	73.5	64.5	70.0	65.0	73.0	74.0
12	75.5	64.0	68.5	70.0	73.0	73.5
	Trial H5		Trial H7		Trial H9	
	4/9/56	4/19/56	5/5/56	5/15/56	5/29/56	6/11/56
13	66.0	66.5	70.5	70.5	76.0	74.5
14	60.5	59.0	62.5	62.5	69.0	71.5
15	61.5	59.5	62.0	*	67.5	67.0
16	58.5	55.5	61.5	61.0	62.5	64.0
17	62.0	60.5	66.0	65.5	72.0	71.5
18	66.0	65.5	69.5	*	73.5	75.0
19	55.5	58.5	58.5	*	65.0	65.0
20	55.5	53.5	61.5	60.0	64.0	65.5
21	60.0	57.5	65.0	65.0	69.0	68.5
22	64.5	61.0	68.5	66.5	74.0	73.5
23	62.5	60.5	67.0	66.0	73.0	73.0
24	54.5	55.5	56.0	*	60.0	*

* Animal was removed due to feed refusal

TABLE VI. APPARENT DIGESTION COEFFICIENTS FOR RATIONS CONTAINING SOYBEAN OIL MEAL AS A PROTEIN SUPPLEMENT

			Apparent digestion coefficients					
Ration	Trial	Lamb	Dry matter	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
4%	H4	1	64.1	65.3	35.4	84.7	42.7	78.3
"	"	3	53.9	55.1	16.2	69.3	23.9	74.2
"	"	11	61.3	61.9	31.3	88.9	30.7	79.0
"	H5	14	60.0	60.5	32.7	89.7	27.5	77.9
"	"	18	61.2	62.5	26.5	87.7	35.7	77.5
"	"	21	54.9	55.6	15.9	84.8	21.6	74.5
"	"	24	58.9	59.8	32.7	94.6	24.0	78.0
6%	H6	3	76.8	78.8	26.2	89.5	78.2	84.5
"	"	9	61.4	62.7	42.9	79.8	39.7	76.8
"	"	2	60.9	62.1	45.2	83.3	37.8	76.0
"	"	10	65.5	66.2	44.6	92.3	45.5	78.0
"	H7	17	73.1	74.7	41.7	89.5	62.9	84.2
"	"	13	73.7	75.6	28.9	87.5	75.4	80.2
"	"	23	73.8	75.2	43.4	92.3	63.6	84.0
"	"	21	74.2	75.7	37.0	90.7	72.7	80.6
8%	H8	5	71.8	73.7	54.6	89.1	66.7	79.7
"	"	3	79.8	81.3	57.3	87.4	78.2	86.9
"	"	6	80.2	81.6	67.4	93.1	74.5	87.3
"	"	2	70.1	71.4	58.1	90.9	54.2	82.2
"	H9	22	81.7	83.4	63.2	90.2	82.8	86.8
"	"	19	76.8	78.8	53.1	87.9	80.0	81.7
"	"	14	76.0	77.9	55.4	81.0	73.4	83.5
"	"	17	76.7	78.1	57.2	90.1	72.2	84.2

TABLE VII. APPARENT DIGESTION COEFFICIENTS FOR RATIONS CONTAINING SESAME MEAL AS A PROTEIN SUPPLEMENT

			Apparent digestion coefficients					
Ration	Trial	Lamb	Dry matter	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
4%	H4	5	54.8	55.4	29.6	90.0	19.8	73.7
"	"	8	56.2	57.3	33.0	91.5	20.9	76.0
"	"	12	54.6	55.6	31.4	89.3	17.0	75.8
"	H5	13	68.2	69.6	27.3	93.3	51.1	80.5
"	"	17	55.3	56.7	21.4	86.4	21.5	75.7
"	"	19	59.2	60.6	42.3	92.1	24.6	78.4
"	"	20	53.2	54.5	24.1	86.1	17.2	74.1
6%	H6	1	75.6	77.8	41.2	87.7	71.1	85.1
"	"	5	61.6	63.2	41.8	83.7	41.5	76.2
"	"	6	65.5	67.4	37.3	82.4	54.4	77.1
"	"	7	61.4	63.2	38.9	85.1	44.1	74.8
"	H7	14	58.3	59.7	36.4	86.7	32.6	75.2
"	"	20	75.2	77.0	44.9	92.2	69.3	83.6
8%	H8	1	77.5	79.8	54.8	93.4	78.6	83.0
"	"	9	65.4	67.7	47.2	90.0	55.7	75.6
"	"	7	74.0	76.1	54.2	94.5	66.3	83.4
"	"	11	70.0	72.1	56.7	92.1	58.7	80.3
"	H9	23	76.2	78.8	51.9	93.3	77.0	82.5
"	"	15	77.2	79.2	57.8	92.9	73.9	84.3
"	"	13	77.0	79.4	44.7	93.3	80.0	83.0

TABLE VIII. APPARENT DIGESTION COEFFICIENTS FOR RATIONS CONTAINING COTTONSEED MEAL AS A PROTEIN SUPPLEMENT

Ration	Trial	Lamb	Apparent digestion coefficients					
			Dry matter	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
4%	H4	4	58.3	58.9	24.5	90.5	33.4	73.0
"	"	9	64.6	65.5	31.5	89.7	42.3	79.0
"	H5	15	55.3	57.1	8.5	82.8	28.1	74.7
"	"	16	57.2	58.4	18.1	93.5	29.3	74.4
"	"	22	60.1	61.6	19.5	72.1	37.8	77.5
"	"	23	60.2	61.0	22.9	94.4	30.0	77.9
6%	H6	8	67.3	68.3	40.0	94.2	52.7	78.6
"	"	12	67.1	68.2	35.5	94.1	52.3	79.2
"	"	11	54.1	54.2	30.6	89.0	23.1	72.6
"	H7	16	57.7	58.3	28.4	89.4	35.8	72.6
"	"	22	60.4	61.7	27.0	91.7	43.2	74.0
8%	H8	4	74.2	76.0	42.2	91.3	76.2	79.8
"	"	8	71.5	72.3	45.6	96.4	64.5	79.0
"	"	10	71.6	72.7	45.8	95.1	63.5	80.6
"	"	12	70.1	71.5	42.3	92.0	64.2	78.7
"	H9	21	64.6	66.0	30.3	88.9	55.2	76.4
"	"	20	79.5	81.0	49.1	95.4	82.0	84.1
"	"	16	72.7	74.1	45.0	93.3	67.8	80.8
"	"	18	77.6	79.1	49.1	92.1	77.3	83.8

TABLE IX. NITROGEN RETENTION FOR LAMBS FED RATIONS CONTAINING SOYBEAN OIL MEAL AS A SOURCE OF PROTEIN

Percent protein in ration	Trial	Lamb	Nitrogen (gm.) Intake	Feces	Urine	Retention
4	H4	1	3.94	2.54	1.36	0.04
"	"	3	3.94	3.30	1.64	-1.00
"	"	11	3.94	2.70	1.93	-0.69
"	H5	14	3.91	2.63	2.17	-0.89
"	"	18	3.91	2.87	2.26	-1.22
"	"	21	3.91	3.29	1.76	-1.14
"	"	24	3.91	2.64	2.05	-0.78
6	H6	3	5.82	4.29	2.16	-0.63
"	"	9	5.82	3.32	2.34	0.16
"	"	2	5.82	3.21	2.53	0.08
"	"	10	5.82	3.22	2.54	0.06
"	H7	17	5.82	3.39	2.24	0.19
"	"	13	5.82	4.14	2.58	-0.90
"	"	23	5.82	3.29	2.49	0.04
"	"	21	5.82	3.66	2.74	-0.58
8	H8	5	8.10	3.68	3.98	0.44
"	"	3	8.10	3.45	4.02	0.63
"	"	6	8.10	2.64	3.54	1.92
"	"	2	8.10	3.39	3.57	1.14
"	H9	22	8.11	2.99	2.68	2.44
"	"	19	8.11	3.81	3.02	1.28
"	"	14	8.11	3.62	3.11	1.38
"	"	17	8.11	3.48	3.64	0.99

TABLE X. NITROGEN RETENTION FOR LAMBS FED RATIONS CONTAINING SESAME MEAL AS A SOURCE OF PROTEIN

Percent protein in ration	Trial	Lamb	Nitrogen (gm.) Intake	Feces	Urine	Retention
4	H4	5	3.98	2.80	2.20	-1.02
"	"	8	3.98	2.66	1.82	-0.50
"	"	12	3.98	2.72	1.43	-0.17
"	H5	13	3.95	2.87	1.72	-0.64
"	"	17	3.95	3.10	1.74	-0.89
"	"	19	3.95	2.28	1.68	-0.01
"	"	20	3.95	2.99	2.12	-1.16
6	H6	1	5.67	3.33	1.94	0.40
"	"	5	5.67	3.29	2.30	0.08
"	"	6	5.67	3.55	2.18	-0.06
"	"	7	5.67	3.46	2.50	-0.29
"	H7	14	5.67	3.60	2.45	-0.38
"	"	20	5.67	3.12	2.24	0.31
8	H8	1	7.47	3.38	2.52	1.57
"	"	9	7.47	3.95	2.38	1.14
"	"	7	7.47	3.42	2.18	1.87
"	"	11	7.47	3.23	3.57	0.67
"	H9	23	7.48	3.60	2.61	1.27
"	"	15	7.48	3.16	1.92	2.41
"	"	13	7.48	4.15	2.18	1.15

TABLE XI. NITROGEN RETENTION FOR LAMBS FED RATIONS CONTAINING COTTONSEED MEAL AS SOURCE OF PROTEIN

Percent protein in ration	Trial	Lamb	Nitrogen (gm.) Intake	Feces	Urine	Retention
4	H4	4	3.93	2.96	1.56	-0.59
"	"	9	3.93	2.69	1.64	-0.40
"	H5	15	3.90	3.56	1.92	-1.58
"	"	16	3.90	3.19	1.80	-1.09
"	"	22	3.90	3.13	1.42	-0.65
"	"	23	3.90	3.00	1.94	-1.04
6	H6	8	5.82	3.49	2.10	0.23
"	"	12	5.82	3.75	1.96	0.11
"	"	11	5.82	4.03	2.23	-0.44
"	H7	16	5.82	4.16	2.89	-1.23
"	"	22	5.82	4.24	1.72	-0.14
8	H8	4	7.61	4.39	1.72	1.50
"	"	8	7.61	4.14	2.16	1.31
"	"	10	7.61	4.12	2.40	1.08
"	"	12	7.61	4.38	2.07	1.16
"	H9	21	7.62	5.31	1.96	0.35
"	"	20	7.62	3.88	1.92	1.82
"	"	16	7.62	4.19	2.15	1.28
"	"	18	7.62	3.88	2.82	0.92

TABLE XII. WEIGHT RECORD FOR LAMBS STUDYING EFFECT OF COTTONSEED HULLS

Trial H 10			Trial H 11		
Lamb	Initial weight 6/30/56	Final weight 7/21/56	Lamb	Initial weight 7/21/56	Final weight 8/1/56
22	75.0	72.0	4	78.5	79.5
8	60.0	62.0	9	65.5	65.5
17	75.0	71.0	6	77.0	76.5
24	61.0	61.5	18	81.0	81.0
14	72.0	73.0	21	71.0	72.0
3	89.0	83.0	23	75.7	76.5
11	80.5	74.5	1	72.0	73.5
5	78.5	76.5	30	79.0	79.0
13	78.5	76.0	10	71.5	75.0
19	67.0	65.0	15	69.0	69.5
32	66.0	67.5	29	67.0	66.5
16	68.0	67.0	31	73.5	75.0

TABLE XIII. APPARENT DIGESTION COEFFICIENTS FOR RATIONS USED IN COTTONSEED HULL TRIALS

			Apparent digestion coefficients					
Ration	Trial	Lamb	Dry matter	Organic matter	Protein	Ether extract	Crude fiber	N-free extract
1	H 10	22	57.8	61.1	64.4	47.1	64.9	58.4
"	"	8	58.9	61.7	62.6	50.7	66.1	59.3
"	"	24	53.9	56.9	64.1	41.8	60.6	53.4
"	H 11	15	58.3	61.1	64.7	44.1	64.4	59.0
"	"	10	60.7	63.7	66.3	51.9	68.8	60.7
"	"	1	61.1	64.3	65.9	48.6	69.6	61.6
2	H 10	17	59.1	61.9	63.4	44.6	66.0	59.7
"	"	11	56.8	59.2	60.2	50.0	62.6	57.3
"	"	13	57.8	60.4	62.2	47.8	64.3	58.2
"	H 11	6	58.1	60.5	62.5	48.9	64.4	58.1
"	"	23	57.3	59.8	59.7	44.6	63.2	58.5
"	"	29	56.7	59.3	59.9	44.6	62.5	57.9
3	H 10	3	61.4	64.5	69.4	32.9	70.6	60.7
"	"	5	60.3	63.2	69.4	36.2	66.1	60.9
"	"	32	58.7	61.4	69.4	38.4	64.7	58.2
"	H 11	9	58.6	61.5	67.4	33.3	64.7	59.2
"	"	31	60.7	63.4	69.2	39.2	66.5	61.0
"	"	30	61.3	64.2	70.4	42.0	66.7	62.1
4	H 10	14	58.0	60.7	64.8	36.7	62.9	59.1
"	"	16	58.4	61.2	64.1	27.7	64.6	59.6
"	"	19	59.9	62.7	67.0	26.4	66.6	60.6
"	H 11	4	61.4	64.0	68.8	37.3	66.7	66.2
"	"	18	59.2	61.9	65.2	30.3	64.7	60.7
"	"	21	60.6	63.1	66.9	27.6	66.4	61.6

TABLE XIV. NITROGEN RETENTION BY LAMBS IN COTTONSEED HULL TRIALS

			Nitrogen			
Ration	Trial	Lamb	Intake gm.	Feces gm.	Urine gm.	Retention gm.
1	H 10	22	11.42	4.06	5.27	2.09
"	"	8	11.42	4.27	5.20	1.95
"	"	24	11.42	4.09	5.22	2.11
"	H 11	15	11.34	4.00	5.31	2.03
"	"	10	11.34	3.82	5.70	1.82
"	"	1	11.34	3.87	5.56	1.91
2	H 10	17	11.48	4.20	5.22	2.06
"	"	11	11.48	4.57	5.47	1.44
"	"	13	11.48	4.34	5.23	1.91
"	H 11	6	11.43	4.28	5.22	1.93
"	"	23	11.43	4.61	5.44	1.38
"	"	29	11.43	4.58	5.22	1.63
3	H 10	3	12.03	3.68	6.78	1.57
"	"	5	12.03	3.68	6.34	2.01
"	"	32	12.03	3.68	5.24	3.11
"	H 11	9	11.97	3.90	6.32	1.75
"	"	31	11.97	3.69	6.08	2.20
"	"	30	11.97	3.55	5.62	2.80
4	H 10	14	11.96	4.21	5.73	2.02
"	"	16	11.96	4.30	5.14	2.52
"	"	19	11.96	3.95	5.29	2.72
"	H 11	4	11.92	3.72	6.60	1.60
"	"	18	11.92	4.14	6.56	1.22
"	"	21	11.92	3.95	6.36	1.61

VITA

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