

FISH MEAL AS A PROTEIN SUPPLEMENT IN FINISHING LAMB DIETS¹

H. S. Hussein² and R. M. Jordan

University of Minnesota³, St. Paul 55108

ABSTRACT

An in situ protein degradation trial and two growth trials were conducted to evaluate the use of fish meal (FM) as a protein supplement in feeder lamb diets. Finn cross and Hampshire lambs were given ad libitum access to corn diets, minerals, and water. In Growth Trial 1, four isonitrogenous (12.6% CP on a DM basis) and isocaloric (77% TDN) diets were supplemented with the following: a) 100% soybean meal (SBM); b) 70% SBM + 30% FM; c) 40% SBM + 60% FM; and d) 100% FM on a DM basis. Diets were fed to 144 lambs for 56 d in a randomized complete block (initial BW) design. In Growth Trial 2, four diets were fed to 80 lambs for 42 d in a completely randomized design with treatments arranged as a 2 × 2 factorial. Main effects in Growth Trial 2 were dietary CP level (13.3 or 14.9%) and source (SBM or SBM + FM). Alfalfa hay was used as the roughage part of each diet. In situ CP degradation (determined in cattle) of SBM, FM, and corn fed in both growth trials were 77.8, 52.3, and 56.8%, respectively. In neither growth trial was ADG affected ($P > .05$) by dietary CP source. Lambs gained faster ($P < .05$) when the CP level was increased from 13.3 to 14.9% in Growth Trial 2. In both trials, protein efficiency ratio (grams of gain/grams of protein intake) and energy efficiency ratio (grams of gain/kilograms of TDN intake) were not different ($P > .05$) among diets. Because of the low ruminal degradation of corn protein, the relative value of SBM and FM in full-fed, high-corn diets was comparable.

Key Words: Sheep, Protein Degradation, Fish Meal, Soybean Meal, Corn

J. Anim. Sci. 1991. 69:2115-2122

Introduction

The extent of ruminal protein degradation is an important consideration in feeding ruminants because it determines the amount of feed protein available for ruminal microbes and the amount available for intestinal digestion by the host animal. Fish meal (FM) is considered by the ARC (1980) to be a protein source that is lowly degradable in the rumen that may enhance animal performance by

complementing the microbial protein at the duodenum. Positive responses to replacing highly degradable protein sources with FM in ruminant diets have been reported (Smith et al., 1980; Cottrill et al., 1982; Ekern, 1982; Oldham and Smith, 1982; Oldham et al., 1985; Bruckental et al., 1989). Such responses have been derived from feeding high-milk-producing or quickly growing ruminants diets based on barley grain, corn silage, or grass silage, which have much higher degradable protein than other basal dietary feeds such as corn grain (NRC, 1985a). Whether FM will improve performance of growing-finishing ruminants fed high-corn diets is not known. The objective of this study was to evaluate replacing soybean meal (SBM) as a highly ruminally degradable protein source with FM in high-corn diets fed on an ad libitum basis to finishing lambs in two growth trials.

¹Published as paper No. 17637 of the Scientific Journal Series of the Minnesota Agric. Exp. Sta. on research supported by Dept. of Anim. Sci., Univ. of Minnesota.

²Present address: Dept. of Anim. Prod., Faculty of Agric., Univ. of Alexandria, Alexandria, Egypt.

³Dept. of Anim. Sci.

Received December 13, 1989.

Accepted October 12, 1990.

Materials and Methods

In Situ Trial. Corn, SBM, and FM⁴ used in Growth Trials 1 and 2 were from the same sources. A representative sample of each ingredient was evaluated using heat-sealed⁵ 6-cm × 10-cm dacron polyester⁶ bags with an average pore size of 52 ± 16 μm. Samples were ground through a 1-mm screen and .5 g was weighed into each bag. Bags were tied to nylon lines that averaged 60 cm in length and were weighted at one end. An empty bag (blank) was attached to each line and seven lines (one for each sampling time) were used daily. All lines except the 0-h line were suspended in the rumen of a lactating Holstein cow approximately 2 h after the morning feeding. The cow was surgically (using of local anesthesia) fitted with a ruminal cannula made of soft plastic, was housed in a well-ventilated barn, and was milked twice daily. The cow had free access to water and was fed a diet formulated to meet its nutrient requirements according to the NRC (1988). The cow's diet consisted of 34% corn silage, 16% alfalfa hay, 16% alfalfa pellets, and 34% grain mix (DM basis). The grain mix was based on corn, oats, SBM, and a vitamin-mineral mix. Bags were removed from the rumen 2, 4, 8, 12, 16, and 24 h postimmersion, washed with water, and squeezed until the runoff was clear. Bags then were dried at 65°C for 48 h and weighed. The *in situ* technique was conducted on two consecutive days to obtain duplicate measurements. Nitrogen remaining in bags was determined by the macro-Kjeldahl procedure (AOAC, 1980). Disappearance of N from dacron bags vs time in the rumen was expressed as a percentage of the original N weighed into the bags. The blank bags were used to correct for possible contamination from ruminal fluid and bacteria that were not removed by washing. Rate of N disappearance (rate of digestion) was estimated as the slope of the regression of the natural logarithm of the percentage of N remaining vs incubation time in the rumen (i.e., 2 to 24 h). Degradation

of CP was estimated by the equation of Mathers and Miller (1981) using a rate constant for passage of undegraded CP from the rumen of .05 h⁻¹.

Management of Animals. Finn cross and Hampshire ewe and wether lambs were used in both growth trials. They were moved from legume pastures to drylot (a well-ventilated sheep barn) and were fed corn with alfalfa hay for 3 wk before the onset of the study (i.e., the 1st wk of August). Lambs had free access to water and a mineral mix composed of limestone and trace mineralized salt at a ratio of 1:1. All lambs were sheared 1 wk before the beginning of the trials; they were healthy and did not require any specific medical care throughout the trials. In both trials, high-corn diets (with alfalfa hay⁷ as the roughage component) were fed twice daily in a 4.9-m × 4.9-m pen bedded with straw. The feeder and waterer of each pen were cleaned daily before the morning feeding. Because alfalfa hay was fed in limited amounts, the feed refusals were only concentrate mixes.

In Growth Trial 1, 144 lambs were weighed and allotted to three blocks according to their initial BW, which averaged 35.4, 31.6, and 28.0 kg for heavy, medium, and light lambs, respectively. Within blocks, lambs were assigned by sex and breed type groups to four pens (12 lambs each). Lambs were fed four isonitrogenous (12.6% CP on a DM basis) and isocaloric (77% TDN) diets for 56 d. Diets were assigned randomly to the four pens of each block; each diet was replicated three times. Treatments were concentrate mixes based on ground corn grain with one of four

TABLE 1. INGREDIENT AND CHEMICAL COMPOSITIONS OF CONCENTRATE MIXES FED TO LAMBS IN GROWTH TRIAL 1

Item	Protein supplement ^a			
	100 SBM	70 SBM- 30 FM	40 SBM- 60 FM	100 FM
	% of DM			
Ingredient composition				
Ground corn	87.9	88.7	89.3	90.1
SBM	12.1	7.9	4.3	—
FM	—	3.4	6.4	9.9
Chemical composition				
CP	13.6	13.4	13.2	13.3

^aSoybean meal (SBM) and fish meal (FM) as a percentage of protein supplement on a DM basis.

⁴Menhaden meal (with fish solubles added) containing 56.1% CP and 13.1% ether extract on a DM basis.

⁵Impulse sealer, Electric Heating Equipment Co., LTD, Taiwan.

⁶Erlanger, Blumgart and Co., Inc., Broadway, NY.

⁷Sun-cured, mature, and containing 10.5% CP and 63% NDF (DM basis).

supplemental protein sources (Table 1). These protein sources were 100% SBM, 70% SBM + 30% FM, 40% SBM + 60% FM, and 100% FM on a DM basis. Alfalfa hay was limited to .35 kg DM·lamb⁻¹·d⁻¹, whereas concentrates were available on an ad libitum basis. Alfalfa hay supplied 21.7 to 22.1% of total dietary N. Lambs were weighed every 2 wk and the nutrient requirements were met using the guidelines recommended by the NRC (1985b).

In Growth Trial 2, 80 lambs having similar BW (35.6 kg) were allotted to eight pens (10 lambs each). Homogenous pens were achieved in a manner similar to that used in Growth Trial 1. Treatments were arranged as a 2 × 2 factorial in which CP level and CP source were the main effects to be investigated. Four concentrate mixes were formulated (Table 2) and fed for 42 d. Dietary CP levels were 13.3 and 14.9% on a DM basis. For each CP level, the concentrate mix was based on ground corn supplemented with either SBM or SBM and FM. Fish meal was added to supply 2% of total DM of the grain mixes that contained the combination of SBM or FM. Treatments were assigned randomly to the eight pens with each treatment replicated twice. Alfalfa hay was limited to .24 kg DM·lamb⁻¹·d⁻¹, whereas concentrates were available on an ad libitum basis. Alfalfa hay supplied 11.8 to 13.4% of total dietary N.

Feed Analyses. Samples of the dietary ingredients were analyzed for absolute DM content by drying at 105°C for 24 h. Nitrogen content of dried samples was determined by the macro-Kjeldahl procedure (AOAC, 1980).

TABLE 2. INGREDIENT AND CHEMICAL COMPOSITIONS OF CONCENTRATE MIXES FED TO LAMBS IN GROWTH TRIAL 2

Item	Source and percentage of protein ^a			
	SBM		SBM + FM	
	13.3%	14.9%	13.3%	14.9%
	————— % of DM —————			
Ingredient composition				
Ground corn	90	85	91	86
SBM	10	15	7	12
FM	—	—	2	2
Chemical composition				
CP	14.1	15.9	13.6	15.7

^aSoybean meal (SBM) or SBM plus fish meal (FM) in concentrate mixes containing 13.3 or 14.9% CP on a DM basis.

Statistical Analysis. Results were analyzed using the GLM procedure of SAS (1985). Sources of variations and corresponding degrees of freedom in the ANOVA are presented in Table 3. In situ data were analyzed as a completely randomized design. In both growth trials, pens were used as the experimental units and pen averages were used for the statistical analysis. Data obtained in Growth Trial 1 were analyzed as a randomized complete block design. Orthogonal contrasts were used to test for linear, quadratic, and cubic responses to FM supplementation (Steel and Torrie, 1980). Data obtained in Growth Trial 2 were analyzed as a completely randomized design. Because treatments in Growth Trial 2 were arranged as a 2 × 2 factorial, treatment sums of squares were separated into main effects (i.e., CP level and CP source) and their interaction. When the *F*-test was found to be significant (*P* < .05), the treatment means were compared using Fisher's least significant difference (Fisher, 1949).

TABLE 3. SOURCES OF VARIATIONS AND CORRESPONDING DEGREES OF FREEDOM IN THE ANALYSIS OF VARIANCE OF IN SITU TRIAL, GROWTH TRIAL 1, AND GROWTH TRIAL 2

Source of variations	df
In situ trial	
Ingredient in dacron bag ^a	2
Error	3
Total	5
Growth trial 1	
Diets ^{bc}	3
Initial BW ^d	2
Error (diet × block)	6
Total	11
Growth trial 2	
Dietary CP source ^e	1
Dietary CP level ^f	1
CP source × CP level	1
Error	4
Total	7

^aSoybean meal (SBM), fish meal (FM), or corn.

^bContaining 12.6% CP and supplemented with the following: a) 100% SBM; b) 70% SBM + 30% FM; c) 40% SBM + 60% FM; and d) 100% FM on a DM basis.

^cOrthogonal single df contrasts were used to test for linear, quadratic, and cubic responses to FM supplementation.

^dBlocks averaging 35.4, 31.6, and 28.0 kg.

^eSBM vs SBM + FM.

^fContaining 13.3% vs 14.9% on a DM basis.

TABLE 4. IN SITU EVALUATION OF SOYBEAN MEAL, FISH MEAL, AND CORN FED TO LAMBS IN GROWTH TRIALS^a

Item	Ingredients ^b			SEM
	SBM	FM	Corn	
CP degradation, % ^c	77.8 ^d	52.5 ^e	56.9 ^e	1.2
N disappearance at 0 h, % ^g	25.8 ^e	32.6 ^d	25.9 ^e	.9
N remaining at 24 h, % ^g	4.7 ^e	34.4 ^d	30.9 ^d	1.2
N rate of digestion ^h , h ⁻¹	.117 ^d	.021 ^f	.036 ^e	.002

^aMeans of single observations on two consecutive days.

^bSoybean meal (SBM), fish meal (FM), and ground corn. Corn data are duplicated from Hussein et al. (1991b) because corn fed in both studies were from the same source.

^cDetermined according to the equation of Mathers and Miller (1981) using a passage rate constant of .05 h⁻¹.

^{d,e,f}Means in the same row with different letters in their superscripts differ ($P < .05$).

^gExpressed as a percentage of the original amount placed into the bag.

^hEstimated as the slope of the regression of natural logarithm of the percentage remaining vs ruminal incubation time (i.e., 2 to 24 h).

Results

In Situ Trial. Data obtained using the dacron bag technique are presented in Table 4. Crude protein degradation (percentage) was lower for FM ($P < .05$) than for SBM but was not different ($P > .05$) from that of corn. In contrast, FM had a higher ($P < .05$) proportion of soluble and small particle N (washed out at 0 h) than SBM or corn. Nitrogen disappearance from dacron bags (assumed to be digested) indicated that FM had the slowest ($P < .05$) rate of digestion. Rate of N digestion was slower ($P < .05$) for corn than for SBM.

Growth Trial 1. Daily DMI, ADG, and feed efficiency data are presented in Table 5. Although lambs were fed restricted amounts of alfalfa hay (.35 kg·lamb⁻¹·d⁻¹) but had ad libitum access to their grain mix, intake of grain mix was similar (1 kg·lamb⁻¹·d⁻¹) for all treatments. Average daily gain tended to increase ($P > .05$) with increasing FM in the diet. Due to the similar ($P > .05$) DMI and ADG, feed per gain (grams of DM intake per gram of gain) was not improved ($P > .05$) by the inclusion of FM in the diet. Calculating protein efficiency ratio (PER) as gram of gain per gram of protein intake resulted in a slight increase ($P > .05$) in the efficiency of protein use when FM replaced SBM. Our TDN values for the dietary ingredients were obtained from the NRC (1985b) to calculate the energy efficiency ratio (gram of gain/kilogram of TDN intake). Energy efficiency ratio (EER) tended to increase with increasing FM supplementation, but the differences among diets

were not significant. Fish meal supplementation did not show any linear, quadratic, or cubic effects ($P > .05$) on ADG, feed efficiency, PER, or EER.

Growth Trial 2. Interactions between sources and levels of dietary CP were not observed ($P > .05$). Therefore, only the main effects are presented in Table 6 for DMI, ADG, and feed efficiency. Because lambs in Growth Trial 2 were heavier than those used in Growth Trial 1 (35.5 kg vs 31.7 kg), dietary

TABLE 5. EFFECT OF PROTEIN SOURCE ON FEED INTAKE AND PERFORMANCE OF LAMBS FED HIGH-CORN DIETS (GROWTH TRIAL 1)

Item	Protein supplements ^a				SEM
	100 SBM	70 SBM-30 FM	40 SBM-60 FM	100 FM	
No. of lambs	36	36	36	36	—
Initial BW, kg	31.7	31.5	31.9	31.6	—
ADG, kg	.282	.295	.293	.305	.009
Daily DMI					
Alfalfa hay, kg	.35	.35	.35	.35	—
Concentrate, kg	.97	.99	.98	.98	—
Feed efficiency ^b	4.7	4.6	4.5	4.4	.1
PER ^c	1.67	1.74	1.76	1.83	.05
EER ^d	278	287	288	297	7.4

^aSoybean meal (SBM) and fish meal (FM) as a percentage of DM of the protein supplement.

^bDefined as grams of DM intake/grams of gain.

^cProtein efficiency ratio: grams of gain/grams of protein intake.

^dEnergy efficiency ratio: grams of gain/kilograms of TDN intake.

TABLE 6. EFFECT OF LEVEL AND SOURCE OF PROTEIN ON FEED INTAKE AND PERFORMANCE OF LAMBS FED HIGH-CORN DIETS (GROWTH TRIAL 2)

Item	Protein source ^a		Protein level ^b		SEM
	SBM	SBM-FM	13.3	14.9	
No. of lambs	20	20	20	20	—
Initial BW, kg	35.3	35.7	36.0	35.1	—
ADG, kg ^c	.241	.244	.235	.250	.004
Daily DMI					
Alfalfa hay, kg	.24	.24	.24	.24	—
Concentrate, kg	1.20	1.20	1.20	1.20	—
Feed per gain ^d	6.0	5.9	6.1	5.8	.1
PER ^e	1.17	1.22	1.23	1.16	.04
EER ^f	211	217	208	220	4.8

^aSoybean meal (SBM) or SBM plus fish meal (FM).

^bPercentage of CP on a DM basis of the concentrate fed.

^cProtein level effect ($P < .05$).

^dDefined as grams of DM intake/grams of gain.

^eProtein efficiency ratio: grams of gain/grams of CP intake.

^fEnergy efficiency ratio: grams of gain/kilograms of TDN intake.

energy density was increased by feeding a lower level of hay than that fed in Growth Trial 1. The same intake of concentrates (1.2 kg·lamb⁻¹·d⁻¹) was observed for all diets, even though lambs had ad libitum access to feed. Average daily gain increased ($P < .05$) as CP level increased from 13.3 to 14.9%. However, ADG was not improved ($P > .05$) by replacing 24 and 16% of SBM N with FM N in the low- and high-CP diets, respectively. Feed per gain, PER, and EER were not affected ($P > .05$) by dietary CP source or level.

Discussion

Evaluation of the dietary ingredients in situ indicated that SBM had 77.8% ruminal CP degradation, which was intermediate to the 83% value reported by Armentano et al. (1986) and the 70.6% value reported by Windschitl and Stern (1988) for untreated SBM measured in situ. Crude protein degradation (percentage) of FM was similar ($P > .05$) to that of corn. The 52.3% value detected for FM (Table 4) is in agreement with other in situ measurements using sheep (Ganev et al., 1979). Due to the larger proportion of the undegraded corn-protein fraction relative to the FM-protein fraction, any positive effects of FM vs SBM attributable to lower rates of degradation probably were masked.

Data obtained from Growth Trials 1 and 2 indicated that neither ADG nor feed efficiency of growing-finishing lambs improved ($P > .05$)

by replacing SBM with FM in the diets. Similarly, no differences ($P > .05$) were reported for ADG, DMI, or feed per gain when FM replaced cottonseed meal in diets fed to finishing Holstein steers (Thonney and Hogue, 1985). The absence of a significant response when FM, as a lowly degradable protein source in the rumen, replaced highly degradable protein sources, such as SBM or cottonseed meal, may be attributed to the high amount of corn grain fed to those growing-finishing ruminants. To explain the similar response to FM supplementation detected in the above trials, an attempt was made to calculate the contribution of corn grain to total dietary DM and to the total undegraded dietary protein. Protein degradation values (Table 4) were used with the reported values (NRC, 1985a) for protein degradabilities of cottonseed meal and alfalfa hay (72 and 64%, respectively). Expressing the results as the mean of the treatments of Growth Trial 1, Growth Trial 2, and the steer trial (Thonney and Hogue, 1985) plus or minus the standard error indicated that corn was $65.9 \pm .4$, 73.3 ± 1.2 , and $72.0 \pm .7\%$ of total dietary DM and contributed 51.8 ± 1.9 , 61.6 ± 2.1 , and $51.5 \pm .4\%$ of the total undegraded dietary protein, respectively. Total undegraded dietary protein was calculated to be 36.5 ± 1.6 , $34.3 \pm .8$, and $38.6 \pm 1.1\%$, for Growth Trial 1, Growth Trial 2, and the steer trial (Thonney and Hogue, 1985), respectively. These results indicate that the failure to detect

a response to replacing SBM or cottonseed meal with FM was a result both of the high proportion of corn grain in the diet and the low degradation of corn protein. Daily DMI was not affected ($P > .05$) by FM supplementation in Growth Trial 1 or Growth Trial 2. Similar results with steers were reported by Thonney and Hogue (1985).

Calculating efficiency of protein usage from data reported by Thonney and Hogue (1985) resulted in PER of 1.25 and 1.04 g of gain/g of protein intake for FM and cottonseed meal diets, respectively. This trend of increasing PER when cottonseed meal is replaced with FM is consistent with PER data obtained when FM replaced SBM (Tables 5 and 6).

Several growth trials based on feeding high-corn diets supplemented with protein sources other than FM that are lowly ruminally degradable were found to agree with the absence of a response to supplementation with a lowly degradable protein. When untreated SBM was replaced by blood meal in a steer trial or was replaced by either blood meal or meat and bone meal in a lamb trial, no differences ($P > .05$) were detected among diets (Loerch and Berger, 1981). Corn grain supplied, on the average, 80 to 64% of dietary DM fed to steers or lambs, respectively. In contrast, Spears et al. (1980) found that steers gained faster ($P < .05$) when they were fed diets containing 92% corn and supplemented with SBM that had been treated with formaldehyde vs untreated SBM. Although initial BW, dietary CP level, and basal dietary ingredients were quite similar for the studies reported by Spears et al. (1980) and Loerch and Berger (1981), contradictory results were observed. Therefore, an attempt was made to calculate the contribution of the supplemental protein tested to total dietary N. Results indicated that formaldehyde-treated SBM in the study of Spears et al. (1980) supplied 21% of dietary N, whereas blood meal in the study of Loerch and Berger (1981) supplied only 10% of dietary N. As a result, differences in contribution of the test protein may explain the contradictory responses detected in these studies.

Fish meal, a lowly ruminally degradable, high-quality protein source, was expected to improve ADG when it replaced highly degradable protein sources such as SBM in Growth Trials 1 and 2 or cottonseed meal in the trial of Thonney and Hogue (1985). However, no advantages were observed. These three trials

are in agreement with other practical feeding trials in Norway (Ekern, 1982), which indicated that FM supplementation of diets fed to growing lambs or steers did not improve performance consistently. Acceptable explanations for these inconsistent results associated with feeding FM to growing ruminants were necessary.

First, the physiological status of the animal can have a large impact on the response to be detected. In this respect, Chalupa (1975) suggested that the potential for ruminal escape protein sources to improve rate and efficiency of gain and N balance is greatest in young, growing ruminants, in which the ruminal microbial amino acid supply is insufficient to meet metabolic amino acid requirements for maintenance and rapid growth. This hypothesis was supported by the early findings of Glimp et al. (1967), who reported that prolonged heating of SBM increased gain and N retention in early-weaned lambs. In agreement, Ørskov et al. (1971) found that ADG and feed per gain increased with increased FM levels in barley diets fed to lambs postweaning. Fish meal supplementation may not be advantageous for heavier growing-finishing ruminants because of their lower protein requirements. These requirements can be met by microbial protein and the escape protein fraction of the basal diet. If diets are based on corn (e.g., Growth Trials 1 and 2), the escape protein fraction is more likely to be substantial. However, the higher ADG associated with the higher CP level fed in Growth Trial 2 suggests that lambs did require a high level of total dietary CP irrespective of its source (i.e., SBM or SBM + FM).

Second, feeding high levels of corn grain to growing-finishing ruminants always is associated with a decrease in ruminal pH. A depression in ruminal pH markedly reduced CP degradation of SBM to levels similar to those observed for meat and bone meal (Loerch et al., 1983). These findings could explain the results of Loerch and Berger (1981), who found little or no response in feedlot performance of steers and lambs when SBM was compared with blood meal and meat and bone meal in high-corn diets. The high levels of corn fed in the present study, and also in the study of Thonney and Hogue (1985), probably lowered ruminal pH. As a result, CP degradation of SBM may have been decreased to levels close to those of FM.

Third, determination of the quantity of non-NH₃ N (NAN) flowing to the duodenum of ruminants may be beneficial in explaining the absence of response to FM supplementation. Mercer et al. (1980) reported that NAN flow (g/d) to the duodenum of lambs fed diets containing groundnut meal or FM was similar. In agreement, replacing SBM with FM in diets fed to lactating cows (Zerbini et al., 1988) and lambs (Hussein et al., 1991a) or continuous culture of rumen contents (Hussein et al., 1991b) resulted in similar ($P > .05$) quantities of NAN leaving the ruminal fermentation. In general, FM depressed ruminal microbial protein synthesis in these studies. Therefore, the greater ($P < .05$) quantities of protein escaping ruminal degradation when FM replaced SBM in the diet may have been counterbalanced by reduced microbial protein synthesis in the rumen. Perhaps lower ruminal NH₃ concentrations and/or limited availability of amino acids or peptides for ruminal microbes from FM may have decreased microbial protein synthesis in Growth Trials 1 and 2.

Implications

Compared with soybean meal, no significant advantages were detected for fish meal supplementation of high-corn diets fed on an ad libitum basis to growing-finishing lambs despite an increase in gain when a higher protein level was fed.

Literature Cited

- ARC. 1980. The Nutrient Requirements of Ruminant Livestock. Agricultural Research Council. Commonwealth Agricultural Bureaux, Slough, UK.
- AOAC. 1980. Official Methods of Analysis (13th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Armentano, L. E., T. A. Herrington, C. E. Polan, A. J. Moe, J. H. Herbein and P. Umstadt. 1986. Ruminal degradation of dried brewers grains, wet brewers grains, and soybean meal. *J. Dairy Sci.* 69:2124.
- Bruckental, I., D. Drori, M. Kaim, H. Lehrer and Y. Folman. 1989. Effects of source and level of protein on milk yield and reproductive performance of high-producing primiparous and multiparous dairy cows. *Anim. Prod.* 48:319.
- Chalupa, W. 1975. Rumen bypass and protection of proteins and amino acids. *J. Dairy Sci.* 68:1198.
- Cottrill, B. R., D. E. Beever, A. R. Austin and D. F. Osbourn. 1982. The effect of protein- and non-protein-nitrogen supplements to maize silage on total amino acid supply in young cattle. *Br. J. Nutr.* 48:527.
- Ekern, A. 1982. Results from feeding trials and practical experience concerning protein feeding of ruminants in Norway. In: E. L. Miller, I. H. Pike and A.J.H. Van Es (Ed.) Protein Contribution of Feedstuffs for Ruminants: Application to feed formulation. Butterworth Scientific, London.
- Fisher, R. A. 1949. The Design of Experiments. Oliver and Boyd Ltd., Edinburgh.
- Ganev, G., E. R. Ørskov and R. Smart. 1979. The effect of roughage or concentrate feeding and rumen retention time on total degradation of protein in the rumen. *J. Agric. Sci. (Camb.)* 93:651.
- Glimp, H. A., M. R. Karr, C. O. Little, P. G. Woolfolk, G. E. Mitchell, Jr. and L. W. Hudson. 1967. Effect of reducing soybean protein solubility by dry heat on the protein utilization of young lambs. *J. Anim. Sci.* 26: 858.
- Hussein, H. S., R. M. Jordan and M. D. Stern. 1991a. Ruminal protein metabolism and intestinal amino acid utilization as affected by dietary protein and carbohydrate sources in sheep. *J. Anim. Sci.* 69:2134.
- Hussein, H. S., M. D. Stern and R. M. Jordan. 1991b. Influence of dietary protein and carbohydrate sources on nitrogen metabolism and carbohydrate fermentation by ruminal microbes in continuous culture. *J. Anim. Sci.* 69:2123.
- Loerch, S. C. and L. L. Berger. 1981. Feedlot performance of steers and lambs fed blood meal, meat and bone meal, dehydrated alfalfa and soybean meal as supplemental protein sources. *J. Anim. Sci.* 53:1198.
- Loerch, S. C., L. L. Berger, D. Gianola and G. C. Fahey, Jr. 1983. Effects of dietary protein source and energy level on in situ nitrogen disappearance of various protein sources. *J. Anim. Sci.* 56:206.
- Mathers, J. C. and E. L. Miller. 1981. Quantitative studies of food protein degradation and the energetic efficiency of microbial protein synthesis in the rumen of sheep given chopped lucerne and rolled barley. *Br. J. Nutr.* 45:587.
- Mercer, J. R., S. A. Allen and E. L. Miller. 1980. Rumen bacterial protein synthesis and the proportion of dietary protein escaping degradation in the rumen of sheep. *Br. J. Nutr.* 43:421.
- NRC. 1985a. Ruminant Nitrogen Usage. National Academy Press, Washington, DC.
- NRC. 1985b. Nutrient Requirements of Sheep (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1988. Nutrient Requirements of Dairy Cattle (6th Rev. Ed.). National Academy Press, Washington, DC.
- Oldham, J. D., D. J. Napper, T. Smith and R. J. Fulford. 1985. Performance of dairy cows offered isonitrogenous diets containing urea or fish meal in early and in mid-lactation. *Br. J. Nutr.* 53:337.
- Oldham, J. D. and T. Smith. 1982. Protein-energy interrelationships for growing and for lactating cattle. In: E. L. Miller, I. H. Pike and A.J.H. Van Es (Ed.) Protein Contribution of Feedstuffs for Ruminants: Application to feed formulation. Butterworth Scientific, London.
- Ørskov, E. R., I. McDonald, C. Fraser and E. L. Corse. 1971. The nutrition of the early weaned lamb. III. The effect of ad libitum intake of diets varying in protein concentration on performance and on body composition at different live weight. *J. Agric. Sci. (Camb.)* 77: 351.
- SAS. 1985. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.
- Smith, T., V. J. Broster and R. E. Hill. 1980. A comparison of sources of supplementary nitrogen for young cattle receiving fibre-rich diets. *J. Agric. Sci. (Camb.)* 95: 687.

- Spears, J. W., E. E. Hatfield and J. H. Clark. 1980. Influence of formaldehyde treatment of soybean meal on performance of growing steers and protein availability in the chick. *J. Anim. Sci.* 50:750.
- Steel, R.G.D. and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach* (2nd Ed.). McGraw-Hill Book Co., New York.
- Thonney, M. L. and D. E. Hogue. 1985. Fish meal or cottonseed meal as supplemental protein for growing Holstein steers. *J. Dairy Sci.* 69:1648.
- Windschitl, P. M. and M. D. Stern. 1988. Evaluation of calcium lignosulfonate-treated soybean meal as a source of rumen protected protein for dairy cattle. *J. Dairy Sci.* 71:3310.
- Zerbini, E., C. E. Polan and J. H. Herbein. 1988. Effect of dietary soybean meal and fish meal on protein digesta flow in Holstein cows during early and midlactation. *J. Dairy Sci.* 71:1248.