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DEVELOPMENT OF A RUMINANT MEAT AND BONE MEAL AND EVALUATION OF HAIR MEAL

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FPRF Industry Summary

Introduction. Meat and bone meal products vary in protein and escape protein contents depending upon raw materials and processing conditions. While some may view this variation as bad, we considered it as an opportunity. Our goal was to determine which raw materials and processing conditions could be used to develop a ruminant meat and bone meal. Also, hog hair is an underutilized product. It is assumed that it has feeding value similar to feather meal and should be processed similarly. However, little information exists in this area.

Objectives. 1) Determine the metabolizable protein value of meat and bone meal products varying in raw materials and processing conditions. 2) Determine escape protein, protein digestibility and protein efficiency of hydrolyzed hair meal.

Summary. Fifty two samples were supplied by the Fats and Proteins Research Foundation. The samples were analyzed for escape protein content and then selected samples were analyzed for total tract true protein digestibility with lambs. Escape values of the meat and bone meal samples ranged from 23 to 56%. True protein digestibilities ranged from 76.4 to 94%. Feather meal samples ranged from 80.8 to 94.9% in protein digestibility and 60.8 to 79% in escape.

Escape protein, protein digestibility and protein efficiency were determined on ten samples of meat and bone meal and poultry byproduct meal. Protein efficiency was the value obtained with measurement of gain of growing beef calves. Escape protein was a very poor predictor of protein efficiency. This suggested that an amino acid was limiting calf growth. Metabolizable amino acids were correlated to the protein efficiency values and it was determined that methionine was the amino acid limiting the value of the meat and bone meal.

Subsequently, a calf growth trial was conducted to determine if feeding a protected methionine product would enhance the value of the meat and bone meal. The protein efficiency value of the meat and bone meal was increased by 70% by the addition of the protected methionine. This clearly shows that methionine is limiting to meat and bone meal for ruminants.

Hog hair was hydrolyzed for 105 to 150 minutes. There was no clear effect of hydrolysis time on protein escape or protein digestibility. However, the protein digestibility of the hair meals was low ranging from 30 to 70%. Hair meal of about 55% digestibility was fed to growing calves. Protein efficiency was determined and compared to feather meal with and without added blood meal. Feather meal had a higher protein efficiency value than hair meal (1.63 vs .94) when they were fed alone but they did not differ (1.51 vs 1.46) when they were fed with 25% blood meal. The hair meal has value and is probably limited only by the low digestibility.

Manuscript #1

Limiting Amino Acid in Meat and Bone

Summary

In situ, digestibility, and growth studies determined characteristics limiting protein efficiency of meat and bone meals. To determine the first limiting nutrient, escape protein and the individual metabolizable amino acids were regressed on the protein efficiency values obtained from the growth studies. Escape protein alone was a poor estimate of protein efficiency. Metabolizable methionine was the amino acid most highly correlated with protein efficiency. These data indicate that protein values of meat and bone meal are related to their contents of metabolizable methionine.

Introduction

In ruminant diets, protein available for absorption at the small intestine is the sum of microbial protein synthesized in the rumen and the feed protein that escapes ruminal digestion. Microbes present in the rumen require nitrogen for microbial growth and protein synthesis. This nitrogen is supplied by feed proteins that are degraded in the rumen as well as by nonprotein nitrogen sources such as urea.

Microbial protein alone, however, may be inadequate to meet the metabolizable protein needs of the growing animal. To meet the metabolizable protein requirement, diets are supplemented with a source of escape protein. Meat and bone meal (MBM) and poultry byproduct meal (PBM), two animal byproducts, are potential sources of escape protein for ruminants.

Past studies with growing ruminants indicate lower daily gain to MBM relative to blood meal may be attributed to the inability of the amino acid composition of MBM to meet the specific needs of the growing calf. In fact, the animal's requirement for metabolizable protein would be better described as a requirement for metabolizable amino acids.

The objectives of this research were: 1) to evaluate MBM and PBM as escape protein sources for growing calves; 2) to determine the first limiting amino acid in MBM and PBM.

Procedure

Growth Trials. Four samples of MBM and six samples of PBM, varying in composition and origin of manufacture, were obtained from various commercial renderers and used as protein sources for growing calves. In each of three growth studies, diets of 44% sorghum silage, 44% corncobs, and 12% supplement were fed to 60 individually fed crossbred steers (568, 530, and 506 lb for Trials 1, 2, and 3, respectively). Steers were supplemented with 4 of the 10 protein sources along with a urea control in each of the three studies. Trials 2 and 3 included a replicated protein source from the previous trial so supplements could be compared across trials. Protein sources were fed at 30, 40, 50, and 60% of the supplemental nitrogen, with urea supplying the remainder. Therefore, regardless of the assigned level, all calves consumed an 11.5% CP diet

(DM basis). Calves were individually fed (at equal percentage of body weight) once daily with Calan electronic gates. Weight data were collected before feeding on three consecutive days at the beginning and end of each 84-day trial. Protein efficiency, calculated as gain above the urea control vs natural protein intake, was plotted for each treatment using the slope-ratio technique.

Digestion Study. A lamb digestion trial was conducted using 24 lambs in three periods to determine the nitrogen digestibility of the same 10 protein sources plus soybean (SBM) relative to a urea control. Lambs were individually fed a basal diet of ensiled corncobs and alfalfa pellets supplemented with one of the protein sources. Diets were fed at a constant percentage of body weight for a 14-day adaptation period and a 7-day fecal collection period. Feed, feces, and orts were collected, dried in a forced-air oven, and analyzed for dry matter and nitrogen content.

Protein Degradation Trial. An in situ Dacron bag trial was conducted to determine the escape protein values of the MBM and PBM samples. A grass hay diet was fed to two mature, ruminally cannulated steers. Approximately four grams of each protein source were placed in 2 x 5 inch Dacron bags (50 micronpore size). Each feedstuff was placed in four bags within each steer. Bags were suspended in the rumen for 12 hours. After removal from the rumen, bags were washed to remove contamination. Total nitrogen was determined before and after ruminal digestion to determine rumen escape of each protein source. Amino acid analysis was completed to determine composition of the protein before and after ruminal digestion.

Results

Growth Trials. Supplements replicated between the three trials did not differ in protein efficiency, therefore results of the three trials were combined. The urea control calves gained .74 lb/day, while maximum gain due to supplementation was .46 lb/day above the urea control (data not shown). Urea control steers gained less ($P<.05$) than steers that received MBM or PBM. Protein efficiency differed among treatments ($P<.10$), ranging from .61 to 1.86 (Table 1 and Figure 1).

Digestion Study. True nitrogen digestibilities by lambs differed among protein sources ($P=.03$), ranging from 79% to 95% (data not shown). The nitrogen digestibility of SBM was 95%, while the PBM sources ranged from 85% to 93% indicating all were highly digestible by lambs. The nitrogen digestibilities for MBM ranged from 79% to 88%.

Protein Degradation Trial. Crude protein content of MBM ranged from 45% to 59%, while PBM sources ranged from 54 to 68% (Table 1). In situ analysis found escape protein values for MBM sources ranged from 42% to 51% of the crude protein escaping ruminal degradation, while PBM sources ranged from 32% to 40% (Table 1). Escape crude protein was moderately correlated ($R^2=.65$) with protein efficiency but had a negative slope (slope=-.05) so as escape crude protein increased, protein efficiency decreased. Ruminants have an amino acid requirement rather than an escape protein requirement, suggesting escape protein may not be the best indicator of protein value.

Amino acid contents of the MBM and PBM sources after the 12-hour ruminal in situ digestion were determined and digestible escape amino acid contents (percentage of crude protein) were calculated for each protein source. To determine the first limiting amino acid, digestible escape amino acids were regressed on the protein efficiency values. Metabolizable methionine was the amino acid most highly correlated (R^2=.37, slope=2.2, P=.06) with protein efficiency, whereas other amino acids were either poorly correlated or had negative slopes (Table 2). These data indicate that protein quality of MBM and PBM for ruminants is limited by the amount of digestible escape methionine. Added methionine that escapes ruminal digestion may increase protein efficiency.

Table 1. Protein degradabilities and efficiencies

Source[a]	Crude protein[b]	Escape protein[c]	Ash[b]	Protein efficiency[d]
MBM 1	58.5	45.2	24.7	0.70[e]
MBM 2	45.0	51.0	40.5	0.61[e]
MBM 3	56.1	41.7	25.3	0.79[e]
MBM 4	58.4	44.3	30.6	0.77[e]
PBM 1	66.0	34.3	16.3	1.12[ef]
PBM 2	63.4	39.8	19.8	1.16[ef]
PBM 3	67.9	38.7	12.3	1.20[ef]
PBM 4	58.5	33.9	22.0	1.86[g]
PBM 5	56.3	32.0	24.0	1.12[ef]
PBM 6	53.5	32.0	19.3	1.54[f]

[a]Meat and bone meal (MBM) and poultry byproduct meal (PBM) sources.
[b]Percent of the dry matter.
[c]Percent of the crude protein after 12 hours in rumen.
[d]Additional gain above the urea controls per unit (lb) of protein supplied above the urea controls.
[e,f]Values in the same column with different superscripts differ (P<.10).

Table 2. Regression of metabolizable amino acid content on protein efficiency

Metabolizable amino acid	R^2	Slope	P
Valine	.43	-1.5	.04
Cystine	.40	-1.4	.05
Methionine	.37	2.2	.06
Isoleucine	.08	.9	.44
Lysine	.004	.1	.86
Histidine	.001	.2	.92
Tryptophan	.07	4.5	.47

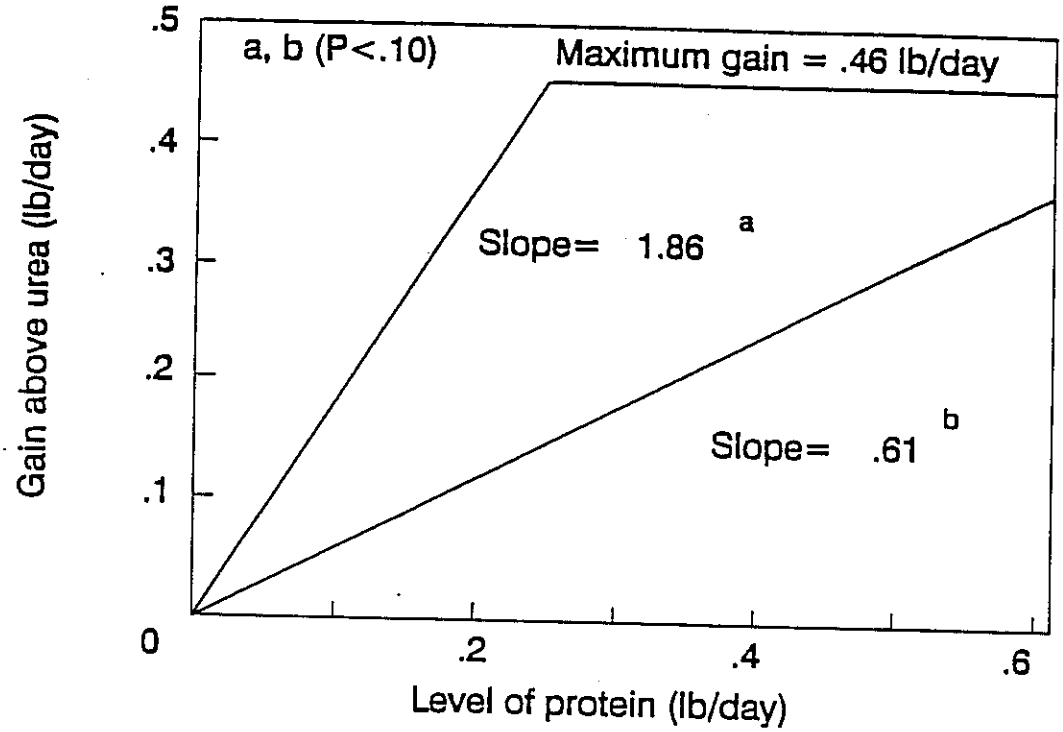


Figure 1. Protein efficiency determined by regression of gain on natural protein intake. Shown are highest and lowest protein efficiencies.

Manuscript #2

Addition of Rumen Protected Methionine and Lysine to Meat and Bone Meal

Summary

A calf growth trial determined the effects of adding rumen protected methionine and lysine to diets containing meat and bone meal. Protein efficiency was greatest when meat and bone meal plus protected methionine was fed. Addition of both protected methionine and lysine to meat and bone meal resulted in a protein efficiency that was similar to when methionine alone was added, indicating lysine was not limiting. These data indicate the first limiting amino acid in meat and bone meal is methionine.

Introduction

To optimize production in growing calves, escape protein is often supplemented to meet the animal's metabolizable protein requirement. Meat and bone meal (MBM) is a rendered animal byproduct often used as a source of escape protein. However, past studies have shown a lower performance response with MBM relative to blood meal. This has been attributed to the escape protein and(or) the amino acid composition of MBM being inadequate to meet the specific needs of the growing calf.

In previous research at the University of Nebraska, small amounts of blood meal added to feather meal improved efficiency of protein use when fed to growing calves. It was theorized that the high lysine content of blood meal complemented the high sulfur amino acid content of the feather meal. Because MBM is also a good source of lysine, it was assumed that MBM would also complement feather meal protein. However, adding MBM to feather meal decreased daily gains indicating an amino acid deficiency in the MBM not seen with the blood meal.

Recent research with growing calves fed various sources of MBM and poultry byproduct meal suggested that metabolizable methionine was the amino acid most closely correlated with protein efficiency, whereas other amino acids were poorly correlated. That research indicates protein quality of MBM and poultry byproduct meal is limited by the amount of metabolizable methionine.

The objective of this trial was to determine whether methionine or lysine is the first limiting amino acid in meat and bone meal.

Procedure

A calf growth trial was conducted using 60 steer calves (515 lb) individually fed diets (DM basis) of 44% sorghum silage, 44% corncobs, and 12% supplement (Table 1). The steers were randomly assigned to treatment and level of treatment protein. Treatments consisted of: 1) urea (control); 2) MBM; 3) MBM plus rumen protected methionine to supply 3.4 g of methionine/lb of supplement; and 4) MBM plus rumen protected methionine and lysine to supply 3.4 g of methionine/lb and 3.4 g of lysine/lb of supplement. Protein sources were fed at 30, 40, 50, and 60% of the supplemental nitrogen, with urea supplying the remainder. Therefore, regardless of the assigned level, all calves consumed a diet containing 11.5% CP (DM basis). Calves were individually fed (at equal percent of body weight) once daily with Calan electronic gates. Weight data were collected before feeding on three consecutive days at the beginning and end of the 84-day trial. Protein efficiency, calculated as gain above the urea control vs natural protein intake, was plotted for each treatment using the slope-ratio technique.

A lamb digestion trial was conducted to determine the nitrogen digestibility of MBM relative to a urea control. lambs were individually fed a basal diet of ensiled corncobs and alfalfa pellets supplemented with MBM. Diets were fed at a constant percent of body weight for a 14-day adaptation period and a 7-day fecal collection period. Feed, feces, and orts were collected, dried in a forced-air oven, and analyzed for dry matter and nitrogen content.

An in situ Dacron bag trial was conducted to determine the escape protein value of MBM. Approximately four grams of MBM was placed in each of four 2 x 5 inch Dacron bags (50 micron-pore size). These bags were then suspended for a period of 12 hours in the rumen of a cannulated steer fed a grass hay diet. After removal from the rumen, bags were washed to remove contamination. Total nitrogen was determined before and after ruminal digestion to determine escape of each protein source. Amino acid analysis was completed on the residue remaining after incubation to determine the composition of the protein escaping ruminal degradation.

Results

Calves that received the MBM treatment gained .70 lb/day, while urea control calves gained .42 lb/day ($P<.05$; Table 2). However, daily gain due to protein supplementation was .89 lb/day in steers that received MBM plus protected methionine. The protein in the MBM plus protected methionine (Figure 1) was utilized with greater efficiency (1.58) than MBM alone (.93) ($P<.10$). Meat and bone meal plus protected methionine and MBM plus protected methionine and lysine had similar protein efficiencies (1.58 vs 1.34) ($P>.30$), indicating that MBM contained adequate metabolizable lysine. The true nitrogen digestibility of MBM was 86.1%, while 53.0% of the crude protein escaped ruminal degradation (Table 3). This crude protein digestibility is good for meat and bone meal. Amino acid content of MBM remaining after 12 hour in situ was determined (Table 3) and the lysine and methionine values are consistent with other values for high ash samples.

The urea control diet failed to meet the metabolizable protein requirement of the animal as seen by the poor performance of the steers. Feeding MBM to provide additional metabolizable protein improved performance but: failed to provide an adequate amount of methionine. These data indicate the first limiting amino acid in MBM for growing calves is methionine.

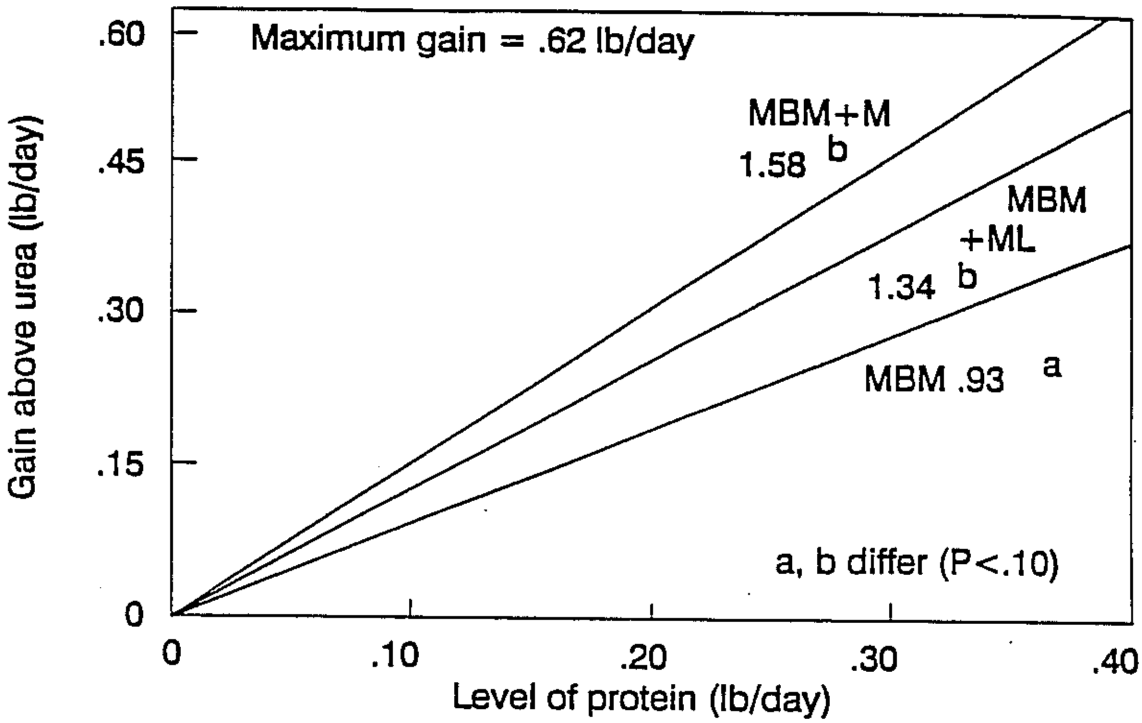


Figure 1. Protein efficiency of calves fed meat and bone meal (MBM), meat and bone meal plus methionine (MBM+M), and meat and bone meal plus methionine and lysine (MBM+ML).

Table 1. Composition of supplements fed to steers

Ingredients	Contents, % of DM			
	Urea	MBM[a]	MBM plus M[a]	MBM plus ML[a]
Meat and bone meal	—	87.5	87.5	87.5
Urea	15.1	5.2	5.2	5.2
Soybean hulls	72.7	2.3	1.2	
Protected methionine	—	—	1.1	0.8
Protected methionine + lysine	—	—	—	1.5
Dicalcium phosphate	7.2	—	—	—
Salt 2.5	2.5	2.5	2.5	
Ammonium sulfate	1.7	1.7	1.7	1.7
Trace mineral premix	0.4	0.4	0.4	0.4
Vitamin premix	0.3	0.3	0.3	0.3
Selenium premix	0.1	0.1	0.1	0.1

[a]Meat and bone meal, meat and bone meal plus methionine, and meat and bone meal plus methionine and lysine, mixed with urea supplement to supply 30, 40, 50, or 60% of supplemental protein.

Table 2. Performance of calves fed meat and bone meal

Supplement[a]	Daily gain, lb	Daily feed, % body weight	Gain/ feed
Urea	.42[b]	2.10	.038[b]
MBM	.70[c]	2.10	.062[c]
MBM+M	.89[d]	2.10	.078[d]
MBM+ML	.84[cd]	2.10	.074[cd]

[a]Meat and bone meal, meat and bone meal plus methionine, and meat and bone meal plus methionine and lysine.
[b,c,d]Values in the same column with different superscripts differ ($P<.05$).

Table 3. Crude protein, escape protein, N digestibility, and amino acid content of meat and bone meal

Item	Meat and bone meal
Crude Protein, %	39.5
N escape[b]	53.0
N digestibility, %	86.1
Arginine	10.3
Cystine	1.1
Histidine	1.9
Isoleucine	3.5
Leucine	7.1
Lysine	5.9
Methionine	1.7
Phenylalanine	4.0
Threonine	3.9
Valine	5.3

[a]Expressed as a percentage of CP remaining after 12 hour in situ.
[b]Percentage of crude protein remaining after 12 hour in situ.

Manuscript #3

Evaluation of Meat and Bone Meal, Feather Meal and Hair Meal Samples

Summary

Fifty two samples were supplied to us by the Fats and Protein Research Foundation. The samples were analyzed for escape protein content and then selected samples were analyzed for total tract true protein digestibility with lambs. Samples varied in escape values and in total tract digestibilities.

Introduction

Renderers products vary in raw materials and processing conditions. The analysis of these samples was an attempt to quantify the range of products produced. We specifically were interested in the protein escape values and the total tract digestibility values.

Procedures

Fifty two samples were supplied by the Rendering Industry. Dacron bag protein degradabilities were determined on all samples (12 hr). Total tract protein digestibility was conducted on all feather meal and hair meal samples. Several samples of meat and bone meal were selected based on their protein escape values. Both high and low temperature samples were evaluated to try to determine the temperature effect.

Results and Discussion

Escape values of the meat and bone meal samples ranged from 23 to 56% (Table 1). Protein digestibilities ranged from 76.41 to 94%. Probably more important is the calculated metabolizable protein (MP) value. This is the escape protein minus the indigestible protein. MP values ranged from 25.6 to 46.5%. This would predict a large range in feeding values.

The poultry byproduct meal was comparable to the meat and bone meal samples (Table 2). The hog hair samples were high in escape but low in digestibility. Feather meal samples ranged from 80.8 to 94.9% in digestibility and 60.8 to 79% in escape. The MP values ranged from 44.7 to 72.1.

Overall, there was no obvious effect of temperature on digestibility, escape or MP values.

Table 1. Evaluation of meat and bone meals processed under different conditions in situ escape protein, University of Nebraska, September 3, 1993, beef, pork and mixed species meat and bone meals

Product	Temp.	Time	Type	Method	Average escape	Protein digestion	MP
1	290		Beef	Duke Continuous	44.45		
	315				39.54		
2	270	1.75 hr	Pork	Duke Continuous	35.38		
	305	1.75 hr			29.72		
3	270	60 min	Mixed	Duke Continuous	48.99	93.99	42.98
	305	75 min			46.10	80.59	26.69
4	270	60 min	Hi ash	Duke Continuous	46.39	90.17	36.56
	300	60 min			52.38	94.16	46.54
6	239	1.6 hr	Beef	Carver Greenfield	32.76		
	278	1.58 hr		or Stord Slurry	37.44		
7	110 C	20 min	Pork	Carver Greenfield	20.85		
	140 C	15 min		or Stord Slurry	23.11		
8	110 C	20 min	Mixed	Carver Greenfield	30.94		
	140 C	15 min		or Stord Slurry	35.64		
10	265	50 min	Beef	Stord Continuous	32.57		
	285	50 min			36.92		
12	235	80 min	Mixed	Stord Continuous	43.34		
	270	70 min			40.73		
18	235	3 hr	Mixed	Atlas Low Temp	51.16	77.03	28.19
	285	3 hr			56.05	83.27	39.32
28	110 C	4 hr	Beef	Atlas Low Temp	43.00	87.34	30.34
	125 C	4 hr			46.22	85.93	32.15
29	110 C	4 hr	Pork	Atlas Low Temp	44.85	88.31	33.16
	125 C	4 hr			38.11	95.79	33.90
11	275				41.87	87.66	29.53
	300				49.22	76.40	25.62
17	205				23.59		
	230				22.76		
21	250				48.12		
	285				42.32		
31	215	3-4 hr	Mixed	Mod. Low Temp	36.06	90.11	26.17
	235	3-4 hr		System	38.51		

Table 2. Evaluation of meat and bone meals processed under different conditions in situ escape protein University of Nebraska, September 3, 1993, poultry meal, feather meal and hog hair

Product	Temp.	Time	Type	Method	Average escape	Protein digestion	MP
5	270	30 min	Poultry	Duke Continuous	47.76	88.22	35.98
	300	30 min			42.23	92.20	34.43
13	245	2.5 hr	Poultry	Stord Continuous	38.13		
	275	2.0 hr			42.20		
14	272	1 hr, 18 min	Poultry	Stord Continuous	37.04		
	298	1 hr, 18 min			38.29		
15	272	1 hr, 18 min	Poultry	Stord Continuous	37.40		
	298	1 hr, 18 min			41.79		
19	260		Poultry	Atlas Continuous	37.76		
	275				39.13		
20	275	20 min	Poultry	Stord Waste Heat	41.24		
	295	20 min		Low Temp	36.36		
22	Low	15 min hydro/	Feather		79.03	93.06	72.09
	High	30 min dryer			72.43	94.92	67.35
24	165	30 min hydro	Feather		67.50	92.31	59.81
25	205	2.5 hr hydro	Feather		63.83	80.82	44.65
26	300	80 min	Feather	Batch Cooker	60.77	85.03	45.80
27	110 C	4 hr	Feather	Atlas Low Temp	60.76	84.86	45.62
30	110 C	4 hr	Hog Hair		59.45	60.41	19.90
	125 C	4 hr			50.79	70.68	21.47

Manuscript #4

Protein Value of Hydrolyzed Hog Hair for Ruminants

Summary

Five samples of hog hair were obtained which had been hydrolyzed for 105 to 150 minutes. There was no clear indication of an effect of time on protein escape or digestibility. Escape values were high but digestibility was low (53-58%). Hog hair was fed to growing calves and protein efficiency determined. Hog hair had a protein efficiency value of .94 compared to feather meal at 1.63.

Introduction

The feeding value of hydrolyzed hog hair has not been well documented. Because it is keratin protein and similar to feather meal, it is assumed that processing conditions and feeding values would be similar.

Procedures

Five samples of hog hair were obtained which had been hydrolyzed from 105 to 150 minutes. Escape protein was determined using the dacron bag technique. Total tract protein digestibility was determined using lambs. A urea control was used and the true protein digestibility of the hog hair determined by difference. Digestibility was determined with total fecal collection

A calf growth study was conducted using 60 individually fed growing beef calves (525 lb). The calves were fed a base diet of 44% corn silage and 44% ground corncobs. The protein sources were included in the supplement (12% of diet dry matter). Supplements included a urea control, hair meal, feather meal and each of the meals fed with blood meal (25% of protein supplied by blood meal). The calves were fed for 82 days. Weight gains were regressed against protein intakes to calculate protein efficiencies using the slope-ratio technique.

Results and Discussion

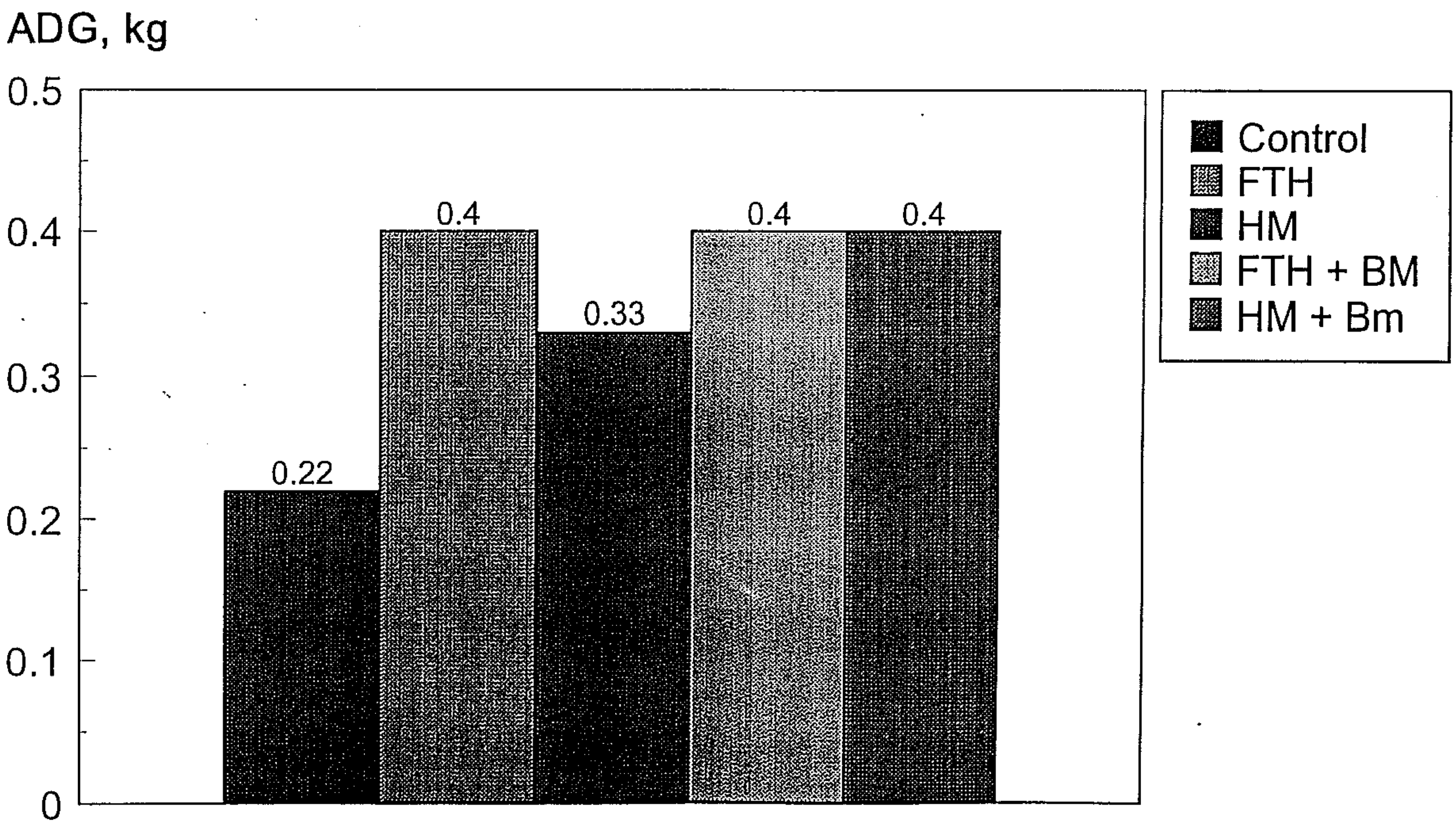
Protein digestibility of soybean meal was about 90% (Table 1). The hair meal samples ranged from 50.8 to 57.8%. There was no clear cut trend for a change in digestibility with processing time. Escape values ranged from 65.1 to 70.8%. Net escape was calculated as the escape protein minus the indigestible protein. The values ranged from 16.7 to 28.6%. The highest value was with the lowest processing time but there was not a clear trend to indicate lower processing times are better. The low protein digestibility seems to be a problem with the hog hair.

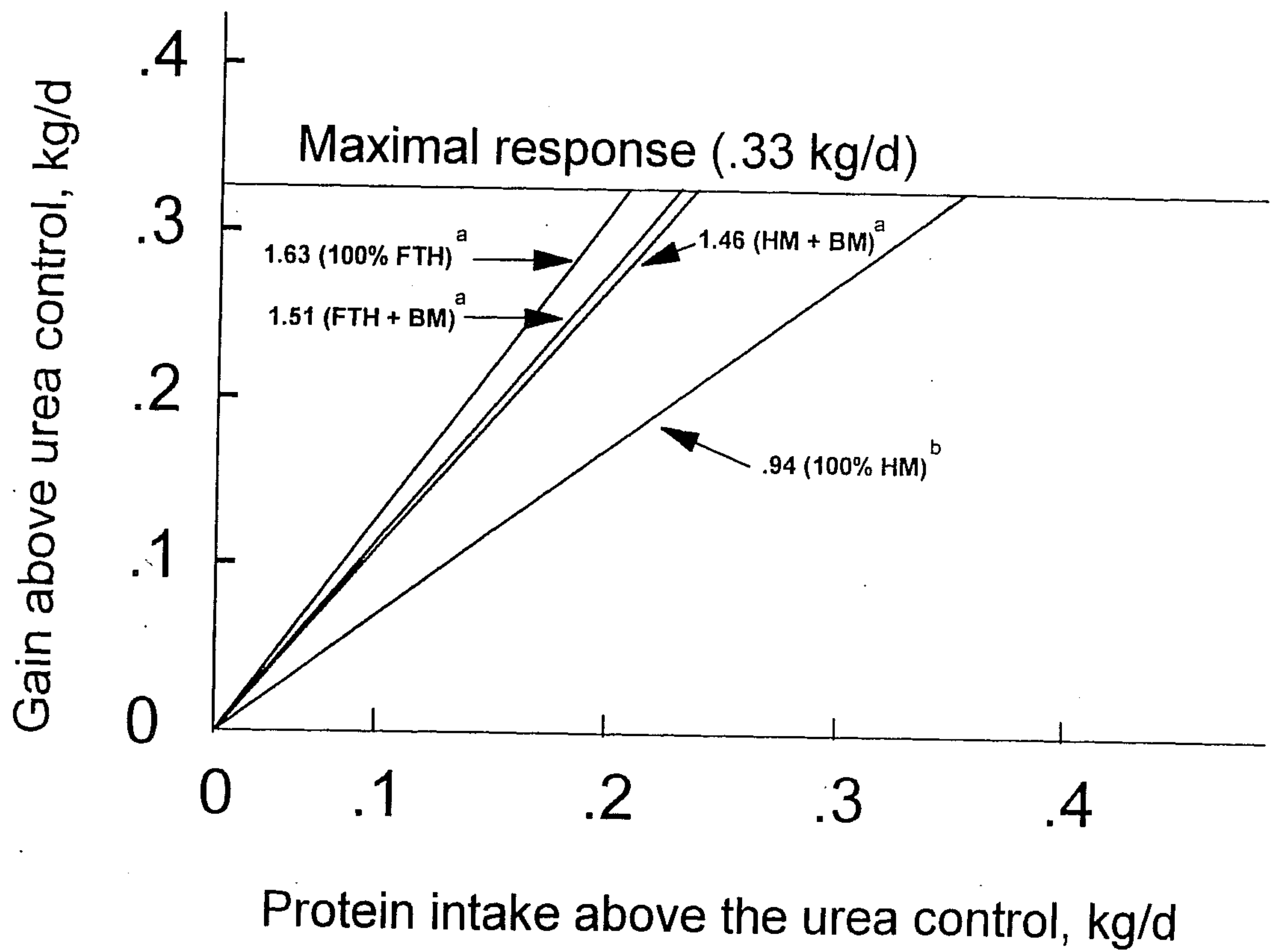
Overall gains for the cattle were higher for the protein sources than for the urea control (Figure 1). Gains for calves fed the hair meal were lower than those fed the other proteins. More important are the protein efficiency values (Figure 2). Feather meal had a higher value than hair meal (1.63 vs .94) when they were fed alone. When fed with 25% blood meal they were similar (1.51 vs 1.46). This shows clearly that the hair meal has value! It is probably only limited by the digestibility of the protein.

Table 1. Effect of processing conditions on protein escape and digestibility in hog hair

Process conditions	Protein escape, %	Protein digestion, %	Net escape[a]
105 min	70.8	57.8	28.6
115 min	65.9	50.8	16.7
120 min	66.5	56.2	22.7
140 min	66.7	53.0	19.7
150 min	65.1	54.1	19.3
Soybean meal	30	89.7	19.7

[a]Protein escape minus indigestible protein.


ADG, kg
0.5
0.4
0.3
0.2
0.1
0
0.22
0.4
0.33
0.4
0.4
Control
FTH
HM
FTH + BM
HM + Bm



Maximal response (.33 kg/d)
1.63 (100% FTH)a
1.51 (FTH + BM)a
1.46 (HM + BM)a
.94 (100% HM)b
Gain above urea control, kg/d
Protein intake above the urea control, kg/d
0
.1
.2
.3
.4