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Summary

Animal byproduct meals were obtained to determine the influence of raw materials and processing conditions on escape protein, protein digestibility, and other measures defining feed value. Escape protein was estimated using both polyester bags in situ and ammonia release in vitro. Lambs were used as a model for cattle to estimate true protein digestibility in vivo. Correlations were performed to test relationships between byproduct characteristics and protein ruminal degradation, and intestinal digestion. Product raw materials (based on ash content) were more related to protein availability than processing temperatures in this study. Escape protein values determined by in situ analysis were highly correlated (r = .92) to escape values determined by ammonia release. However, incubation in situ may overestimate protein degradation due to DM exiting the bag while rinsing. Meat and bone meal ash content was related to both in situ escape protein (r = .51) and escape protein determined through ammonia release (r = .44). Results of this study indicate that animal byproduct meals vary in escape protein but the protein is generally highly digested.

Introduction

Blood meal, meat and bone meal, and feather meal are high in escape protein, relative to oil meals and forages, and increase performance when included in forage-based diets sufficient in rumen degradable protein. Two factors that influence the nutritive value of animal byproduct meals are processing conditions and raw materials.

Renderers apply heat to drive off moisture, extract fat, and eliminate bacterial contamination from animal tissues. This cooking also denatures proteins, creating cross links and insoluble bonds within and between protein chains; enhancing resistance to microbial degradation in the rumen. However, processing at very high temperatures can limit the extent of enzymatic breakdown of proteins, reducing digestibility and absorption in the small intestine.

Variable inputs (deadstock, tankage, meat trimmings and bones) contribute to the great diversity encountered in commercial meat and bone meals. Concentration of meat and bone meal components, specifically bone, hair, and lean tissues, influence protein quantity and quality. Bone content, exhibited through ash, is negatively correlated with crude protein, whereas hair is high in protein but poorly digested. Animal performance with meat and bone meal supplementation has been inconsistent, and may result from inadequate escape protein and(or) poor protein digestibility arising from raw materials or processing conditions.

The objectives of this study were to determine how processing temperature and composition of animal byproduct meals influence in vivo true protein digestibility and escape protein concentrations, and to compare in situ and in vitro ammonia release techniques for measuring escape protein.

Procedure

Meat and bone meal from various species (n = 36), feather meal (n = 9) and blood meal (n = 2) samples were obtained from renderers throughout the United States, and represent various processing conditions and raw material inputs which generate commercially available meals. All samples were incubated in situ and in vitro to estimate escape protein, ashed at 1,112 °F to determine mineral content, and fed to lambs to determine ruminant protein digestibility in vivo.

The results of several lamb digestibility trials were compiled to generate a large data set. Soybean meal and corn gluten meal were included to serve as standards of comparison for crude protein digestibility. In each experiment, individually fed lambs were assigned randomly to treatments, and at least five observations were obtained for each protein source. Fecal samples were acquired during a seven-day collection period which immediately followed a 10-day adaptation phase. Control lambs consumed a basal diet DM consisting of 72.7% ensiled corncobs, 15% alfalfa pellets, 10% finely ground corn, 1.48% urea, and .82% supplemental minerals and vitamins.

To determine true protein digestibility, treatment lambs consumed the basal diet at the same percentage of

body weight (DM basis) as control lambs, with an additional 3.75% of the basal diet DM intake as units of CP from an animal byproduct meal. Test protein sources comprised 27% of the total CP intake for treatment lambs, and were individually weighed and hand-mixed into the basal diet at the time of feed-ing. Apparent CP digestibility was calculated for control animals: {(CP consumed - CP excreted)/CP consumed}. Subsequently, true protein digestibility of animal byproducts was computed using the following formula: (A-(B*C))/D, where: A = digestibility of CP in total treatment diet; B = digestibility of CP in basal feed; C = proportion of total CP in diet supplied by basal feed; and D = proportion of total CP in diet supplied by treatment protein.

Escape protein was determined using both in situ, and in vitro ammonia release techniques. For in situ analysis, four grams of each protein source were weighed into polyester bags in duplicate. Bags were ruminally-incubated for 12 hours using a mature crossbred steer. The animal was adapted to a cool season grass hay diet, and was fed immediately after placement of the bags. Upon removal from the rumen, bags were hand washed in warm water until the rinse water was clear to remove contamination. Escape protein was calculated as the percentage of CP remaining after 12 hours of incubation.

In the ammonia release procedure, triplicate samples of each byproduct containing 20 mg N were weighed into 50 ml in vitro tubes. Soybean meal and treated soybean meal (Soypass) were included to serve as standards for computing escape protein. Rumen contents collected from two ruminally fistulated steers, consuming either grass hay or ground corncobs, was strained through cheese cloth, mixed, and combined with McDougall's buffer in a 1:1 ratio. This inoculum was maintained at 102°F under a constant stream of CO_2, while 30 ml was dispensed into each tube. Following incubation for 18 and 24 hours in a 102°F water bath, tubes were centrifuged and the supernate analyzed for ammonia concentration. Ammonia content as a percent of total N was assessed for each test protein, and compared to the soybean meal standards, in which the escape protein content was known (30 and 78%). This calculation provided a relative degradability, and allowed an estimate of escape protein based on soybean meal equivalence.

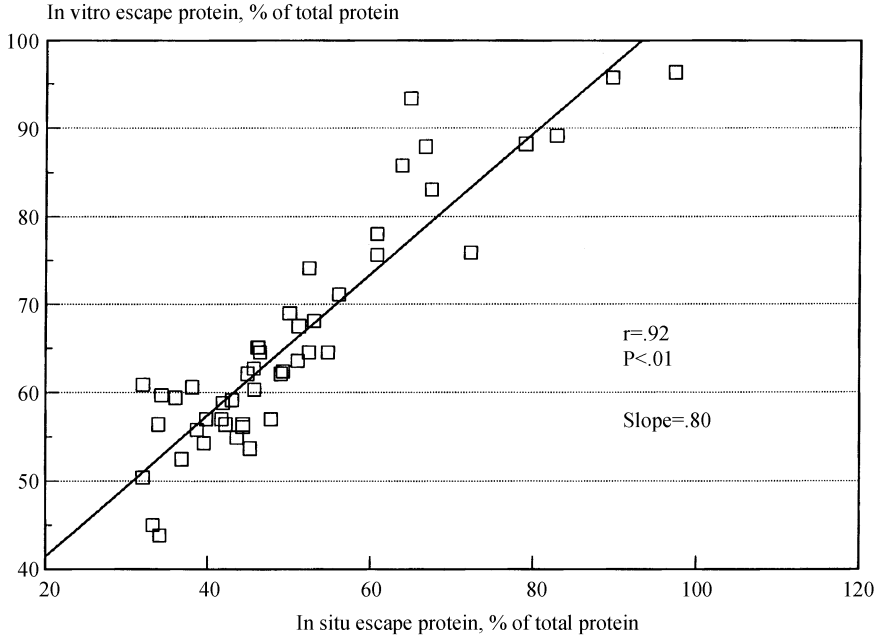

Figure 1. Correlation of soybean meal equivalent value, obtained through ammonia release, and in situ escape protein for meat and bone, and poultry byproduct meals.

Metabolizable protein (MP) and escape protein digestibility (EPD) were determined for individual animal byproducts using computed values for escape protein (EP) and true nitrogen digestibility (TND). Metabolizable protein was calculated as EP - (100-TND), and is the portion of crude protein which escapes microbial degradation and is digested in the small intestine. Escape protein digestibility was determined by dividing MP by EP. Correlations were used to detect relationships between measured and computed values for animal byproducts. Effect of processing temperature on protein availability was tested using the GLM procedure of SAS, with samples separated into low or high temperature groups.

Results

Processing temperatures were known for fifteen of the meat and bone meals. Fourteen of these products stemmed from seven individual batches obtained from different producers. These batches were divided, and the same raw materials were processed at a low and high temperature. Low and high mean processing temperatures were 249°F and 286°F, respectively. Temperature did not influence TND, EP, EPD, or MP, and no significant correlations were exhibited ($P > .05$). Processing temperatures of materials in this study were not to the extreme which would substantially decrease protein digestibility. However, they are within the range routinely used in the rendering industry.

In vitro ammonia release and in situ incubation were highly correlated as measures of escape protein. However, calculations of escape protein based on ammonia release exhibited higher values than those determined in situ, especially in products with higher degradability (Figure 1). This may have been the result of DM loss from the

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Table 1. Summary of analyses and calculated values for animal byproducts

Item (n)	Ash[a]	Crude protein[a]	Escape protein[b]	True nitrogen digestibility	Metabolizable protein[c]	Escape protein digestibility[d]
MBM+PBM[e] (36)			In situ			
Range	12.3 - 50.6	39.5 - 69.5	32.0 - 56.1	76.4 - 97.8	18.6 - 46.5	52.1 - 95.2
Mean	27.2	54.6	43.5	87.8	31.3	72.0
SD	9.3	7.2	6.7	5.2	7.0	10.9
			NH_3 Release[f]			
Range			43.8 - 74.1		31.1 - 58.7	61.1 - 96.4
Mean			59.5		47.4	79.6
SD			6.4		7.0	8.4
Feather meal (9)						
Range	1.2 - 3.1	81.7 - 92.1	50.0 - 82.8	80.8 - 94.9	34.1 - 74.8	68.2 - 93.0
Mean	2.4	86.8	67.1	87.8	54.9	80.7
SD	.7	3.7	10.0	5.2	14.1	9.9
Blood meal (2)						
Range	1.9 - 3.6	82.1 - 93.5	89.6 - 97.3	84.9 - 86.0	75.6 - 82.2	84.4 - 84.5
Mean	2.7	87.8	93.5	85.5	78.9	84.4
SD	1.2	8.1	5.4	.8	4.7	.1
Soybean meal (2)						
Range	7.3 - 7.8	42.8 - 49.3	30.0 - 31.6	91.4 - 91.7	21.7 - 23.0	72.3 - 72.7
Mean	7.5	46.1	30.8	91.6	22.4	72.5
SD	.3	4.6	1.1	.2	.9	.3
Corn gluten meal (1)						
	1.7	63.9	64.9	96.7	61.6	94.9

[a]Expressed as a percentage of dry matter.
[b]Percentage of crude protein remaining after 12 hours ruminal incubation, in situ unless otherwise indicated.
[c]Calculated as: escape protein - (100 - true nitrogen digestibility).
[d]Calculated as: (metabolizable protein/escape protein) x 100.
[e]Meat and bone meal (MBM), poultry byproduct meal (PBM).
[f]Soybean meal equivalent value.

polyester bags during the in situ washing procedure; therefore, underestimating the escape protein content of meat and bone and poultry byproduct meals. Correlations were conducted using escape values obtained through ammonia release, as these were considered to be more accurate estimates. Table 1 summarizes values for measured variables and product components, and illustrates the disparity in values between in vitro ammonia release and in situ procedures.

Ash content of meat and bone meal exhibited a positive relationship with escape protein (r = .44, $P < .01$). Protein identified with bone is comprised predominantly of collagen, and may be more resistant to degradation by ruminal microorganisms than protein in lean tissues. Although ash concentration was related to microbial protein degradation, it had no significant negative relationship to TND (r = -.26, $P = .13$). This suggests the protein associated with bone is adequately digested in the ruminant small intestine. Although ash content was positively related to escape protein, a relationship was not observed between ash and MP (r = .20, $P = .22$).

True nitrogen digestibility of meat and bone meal did not exhibit a strong negative correlation with escape protein (r = -.28, $P = .09$), but the accompanying probability level suggests a negative relationship may exist. High escape protein content in meat and bone meal may stem from either processing technique or raw materials. Unhydrolyzed hair is known to bypass the rumen, and is very resistant to enzymatic degradation. Contamination with hair could explain this correlation, although in the absence of a direct measure, we are unable to make this conclusion.

The digestibility of the escape protein in meat and bone and poultry byproduct meals ranged from 61 to 96%. Only 4 of the 36 samples were below 70%. The average escape protein digestibility of the meat and bone and poultry byproduct meals was equal to that of soybean meal.

Hydrolyzed feather meal samples ranged from 68 to 93% digestibility of the escape protein. Escape values ranged from 50 to 83%.

Metabolizable protein is the protein calculated to be absorbed as amino acids from the small intestine. These MP values ranged from 31 to 59% for meat and bone and poultry byproduct meals. Feather meals ranged from 34 to 75%. This suggests that there is an opportunity to select sources of these products with higher feeding values.

This study indicates meat and bone meal, feather meal, and blood meal possess adequate protein digestibilities, when properly processed, which are comparable to soybean meal and corn gluten meal. Raw materials (based on ash contents) were correlated with measures of feed value of animal byproducts in our evaluation more than processing temperature, and in situ incubation may not be the appropriate means to determine escape protein content of meat and bone meals.

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