Factors Affecting Protein Quality and Amino Acid Digestibility of Meat and Bone Meal and Poultry Byproduct Meal

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Animal protein meals such as meat and bone meal (MBM) and poultry byproduct meal (PBPM) are high in protein but their protein quality and amino acid digestibility can vary. There are several factors that have been reported or hypothesized to influence protein quality of animal protein meals. This paper will summarize some of our research during the last several years to quantitate the effect of factors such as raw material source, processing systems, processing temperatures, processing pressure and ash on the protein quality and amino acid digestibility of MBM and PBPM. A new in vitro assay, the immobilized digestive enzyme assay, will also be discussed for predicting in vivo amino acid digestibility of MBM and PBPM. MBM will be discussed in the first part of the paper and PBPM will be discussed in the second section.

MEAT AND BONE MEAL

Effect of Raw Material Source, Processing System and Processing Temperature On Protein Quality of MBM

A study was conducted in cooperation with the Fats and Proteins Research Foundation in attempt to identify the major commercial factors affecting protein quality of MBM. Thirty-two samples of MBM were processed in different rendering systems at two different temperatures (low vs high). The raw material source varied for the MBM (beef, pork, mixed species). Although there were some significant differences, raw material source did not have any substantial or consistent effect on amino acid digestibility. The type of processing system and processing temperature significantly affected amino acid digestibility (Table 1). The digestibility of Lys and Cys was considerably higher for MBM produced in processing System B than in System A. Moreover, System B generally yielded very high Lys digestibility of 90% or greater. In addition, amino acid digestibility was higher when the MBM was processed at the lower temperature in both Systems A and B, but the temperature effect was greater in System A. At least part of the probable explanation for the lower amino acid digestibilities for System A is that the MBM was processed at higher temperatures than in System B. Cystine was the amino acid that was most affected by processing system and temperature, with the high temperature used in System A yielding very low Cys digestibilities. Finally, it is important to note that the results for System B show that MBM with very high amino acid digestibility can be produced with good processing procedures.

Table 1. Effect of Processing System and Temperature on Amino Acid Digestibility of Meat and Bone Meal[1]

Processing System	Processing Temperature (°C)	Digest. Coefficient (%)	
		Lysine	Cystine
A	132	85	39
A	152	78	20
A	132	81	50
A	152	71	31
B	110	92	71
B	140	90	62
B	110	91	59
B	140	87	51

[1]From Wang and Parsons (1998).

Effect of Pressure Processing on MBM

We have conducted research with MBM to assess the effects of pressure processing on amino acid digestibility. The reason for evaluating pressure processing is due to concerns of bovine spongiform encephalopathy (BSE). The feeding of BSE-infected MBM to ruminants may cause BSE. The consumption of meat from BSE-infected cattle may, in turn, cause Creutzfeldt-Jakob Disease (CJD) in humans. Consequently, extreme restrictions have been placed on the feeding of MBM in the United Kingdom and the feeding of MBM containing ruminant tissue to ruminants was banned in the U.S. BSE and CJD are caused by heat-stable prion proteins that can be at least partially inactivated by pressure cooking. The European Union has often required that MBM be processed at 3 atmospheres (30 gauge psi) for 20 minutes at 133° C (271° F) to reduce the risk of BSE and CJD. It is possible that MBM may have to be pressure processed in the U.S. in the future. However, any future requirements/regulations for MBM processing are unknown. Therefore, several different processing pressures were evaluated in our study.

Processing conventionally-rendered MBM at 15, 30, 45 or 60 psi for 20 min. influenced amino acid digestibility (Table 2). Pressures of 15 and 30 psi produced moderate depressions in digestibility of most amino acids, including Thr, Lys and Met. The reductions in digestibility of Cys were greater than those for the other amino acids. Increasing the pressure to 60 psi produced large decreases in amino acid digestibility for all amino acids, with by far the greatest reduction occurring for Cys. The large reduction in digestibility at 60 psi was due both to the destruction of amino acids and decreased digestibility of amino acids that were not destroyed.

Table 2. Effect of Pressure Processing on Amino Acid Digestibility Coefficients (%) for Meat and Bone Meal[1]

Experiment	Pressure (psi)[2]	Thr	Lys	Met	Cys
1	0	81[a]	76[a]	81[a]	65[a]
	15	76[ab]	67[b]	76[ab]	48[b]
	30	76[ab]	68[b]	76[ab]	50[b]
	45	73[b]	62[b]	75[b]	46[b]
	60	54[c]	41[c]	62[c]	15[c]
2	0	79[a]	70[a]	77[a]	67[a]
	45	66[b]	48[b]	65[b]	36[b]
	60	63[b]	51[b]	63[c]	23[c]

[a-c]Means within a column and experiment with no common superscript differ ($P < .05$).
[1]Shirley and Parsons (2000).
[2]Meat and bone meals processed for 20 min. at the specified pressure.

Effect of Ash Content On Protein Quality of MBM

Another variable that is alleged to influence protein quality and amino acid digestibility of animal meals is ash content. Meals that contain higher ash are generally considered to be of lower protein quality and have lower amino acid digestibility. However, when one reviews the literature, there are limited data to support the effect of ash on protein quality and little or no data to support an effect of ash on amino acid digestibility. The partial results of one of our studies to evaluate the effect of ash for MBM are summarized in Table 3. Increased ash content from 9-44% had little or no negative effect on amino acid digestibility. There was a decrease in digestibility of amino acids when the ash increased to 63% (all bone sample). In contrast to amino acid digestibility, increased ash did have a negative effect on protein quality as measured by protein efficiency ratio (PER) in a 10-day chick growth trial. In the PER trial, 10% CP diets were fed in which the MBM provided the only source of dietary CP. The PER values were calculated by dividing the weight gain (g) by the protein intake (g). The reduction in protein quality (PER values) due to increased ash was not due to reduced amino acid digestibility but was due to poorer total amino acid balance or profile; that is, the analyzed level of sulfur amino acids and Trp per unit of CP decreased as the ash content increased. The latter effect is probably due to the increased bone content in the higher ash samples. Bone contains approximately 25 to 30% CP and the protein is of very low quality due to extreme deficiencies of sulfur amino acids, particularly Cys, and Trp. Thus, our results indicate that the protein quality of MBM does, indeed, decrease with increasing ash content, but the reduction is due to a poorer balance of **total** amino acids, not decreased amino acid digestibility.

Table 3. Amino Acid Digestibility and Protein Efficiency Ratio (PER) of Meat and Bone Meals Varying in Ash[1]

Ash (%)	Lys digest. (%)	Met digest. (%)	PER
9	89[a]	88[a]	-
16	86[a]	87[a]	3.3[a]
26	79[b]	81[a]	3.0[b]
35	82[ab]	82[a]	2.1[c]
44	85[a]	82[a]	1.7[d]
63	72[c]	53[b]	-

[a-b]Means within a column with no common superscripts are different ($P < 0.05$).
[1]Shirley and Parsons (2001).

In contrast to our results, Ravindran et al. (2002) recently reported that digestibility of several amino acids in 19 MBM from New Zealand was negatively correlated with ash content. The amino acid most highly correlated with ash was Lys. A summary of the ash, CP, total Lys and Lys digestibility coefficients for the MBM samples that varied most in ash is shown in Table 4. It is clear that the higher ash samples had lower Lys digestibility coefficients. The reason for the discrepancy between the Ravindran et al. (2002) and our study (Shirley and Parsons, 2001) is unknown. One possible reason is that the differences in Lys digestibility in the Ravindran et al. (2002) study were partially due to processing conditions and not ash since the samples were selected at random from different plants. Also, as discussed by Ravindran et al. (2002), part of the ash correlation could have been due to the lower amino acid concentrations in the higher ash MBM samples. The Ravindran et al. (2002) data are **apparent digestibility** and these values may be reduced at lower amino acid intakes due to no correction for endogenous amino acids. As shown in Table 4, the lower ash MBM did indeed contain substantially higher Lys concentrations (about 45% more) than the higher ash samples.

Table 4. Composition and Apparent Lysine Digestibility of Selected Meat and Bone Meals Varying in Ash from Ravindran et al. (2002).

Sample no.	Ash (%)	CP (%)	Total Lys (%)	Lysine digestibility coefficient (%)
3	13	67	3.93	75
16	19	65	3.14	77
7	22	58	3.37	80
14	23	52	2.90	82
19	32	60	2.62	61
8	33	51	2.60	65
13	44	49	2.28	45
9	56	38	1.69	44

POULTRY BY-PRODUCT MEAL

Variation in Protein Quality and Amino Acid Digestibility for PBPM

The CP, ash, fat, Lys and Thr digestibility coefficients and PER values for 10 randomly selected PBPM from different processing plants is shown in Table 5. The average values for the 10 samples agreed well with most table values but there was substantial variation among individual samples for some components. For example, ash values ranged from 9 to 23%, Lys digestibility ranged from 72 to 89%, and PER values ranged from 2.1 to 3.3.

Table 5. Composition and Protein Quality for Random Samples of Poultry Byproduct Meal (%)[1]

Sample	CP (%)	Ash (%)	Fat (%)	Lys digest. (%)	Thr digest. (%)	PER[2]
1	61	20	14	89	84	2.8
2	68	9	13	76	79	2.9
3	62	15	16	72	75	2.1
4	59	23	16	88	86	2.4
5	65	16	13	83	84	2.9
6	63	14	16	86	83	2.8
7	63	15	12	83	83	3.3
8	60	17	11	75	75	2.8
9	63	15	14	76	80	3.3
10	63	16	14	81	81	2.8

[1]Parsons et al. (unpublished).
[2]PER = protein efficiency ratio.

Effect of Raw Material Source, Processing System and Processing Temperature on Amino Acid Digestibility of PBPM

A second study was conducted in attempt to better identify the reasons for variation in protein quality of PBPM among samples (Wang, 1996). Twelve samples of PBPM were obtained from commercial plants and the samples represented 3 different raw material sources, 4 different processing systems and 2 different processing temperatures within each plant. The processing temperatures generally varied by 15° C between the low and high temperature within a plant (e.g., 133 to 148° C). A summary of the results of the study is shown in Table 6. Amino acid digestibility was generally lowest for the PBPM that contained secondary poultry nutrient (SPN) and hatchery waste. Digestibility of amino acids was similar for 3 of the 4 processing systems but was lower for System D than the others. Amino acid digestibility was slightly higher at the lower processing temperature.

Table 6. Effect of raw material, source, processing system and processing temperature on digestibility of selected amino acids in poultry by-product meals[1]

	n	Lys	Cys	Met	Thr
Raw material source					
PBPM only	8	83.4[ab]	52.0	83.9[ab]	81.0[ab]
PBPM with SPN[2] and blood	2	86.0[a]	56.1	90.9[a]	82.4[a]
PBPM with SPN and hatchery waste	2	81.2[b]	50.8	87.3[b]	78.7[b]
Processing system					
A	2	83.2[a]	52.8[a]	89.7[a]	84.1[a]
B	6	85.0[a]	55.6[a]	89.9[a]	81.6[a]
C	2	84.7[a]	55.0[a]	89.5[a]	81.6[a]
D	2	77.9[b]	40.2[b]	86.5[b]	74.4[b]
Processing temperature					
Low	6	85	54	90[a]	82[a]
High	6	82	50	88[b]	80[b]
Pooled SD		3.6	8.3	2.7	3.4

[1]From Wang (1996).
[2]SPN = secondary poultry nutrient or DAF sludge.

Effect of Ash Content for PBPM

The results of two studies on ash content and protein quality of PBPM are summarized in Table 7. The results clearly indicate no consistent effect of ash on amino acid digestibility and also no substantial effect of ash on PER values. The lack of effect of ash on PER may be due to the much smaller range in ash values among PBPM samples than previously observed for MBM samples earlier.

Table 7. Amino Acid Digestibility and Protein Efficiency Ratio (PER) for Poultry Byproduct Meals Varying in Ash

Ash (%)	Lys digest. (%)	Met digest. (%)	PER
7[1]	70	76	2.43
16[1]	74	80	2.50
9.6[2]	79	86	3.01
10.0[2]	89	92	3.45
11.6[2]	83	88	2.92
12.0[2]	87	91	3.51

[1]Johnson and Parsons (1997) and Johnson et al. (1998).
[2]Cramer (2003). Amino acid digestibility determined in conventional roosters.

An Enzyme-Based Amino Acid Digestibility Assay for Animal Protein Meals

There continues to be a great need for rapid laboratory assays that can be used to predict or estimate protein quality of animal meals so that expensive, time consuming, animal trials do not have to be conducted. It has been shown previously that the pepsin N digestibility test is somewhat useful, particularly if the level of pepsin is reduced from .2 to .002 or .0002%. A new system that uses immobilized enzymes has been developed by Dr. Chuck Schasteen's group at NOVUS International and the method is known as the Immobilized Digestive Enzyme Assay (IDEA) (Schasteen *et al*., 2002). The original IDEA system used pepsin in a low pH digestor followed by neutralization and digestion with chymotrypsin, trypsin and intestinal peptidase in a second digestor. The original system has been modified using glass derivatization and enzyme immobilization to produce kits for MBM, PBPM and soybean meal that will yield results within two hours. The IDEA assay produces amino acid digestibility values that are highly correlated with cecectomized rooster digestibility values determined in my lab (Schasteen et al., 2002). The IDEA system is currently also being evaluated for fish meal and distillers dried grains with solubles. Research with the IDEA system indicates that it is a rapid, robust and inexpensive predictor of amino acid digestibility in several important feedstuffs.

The results summarized in Table 8 show that the IDEA results can be used successfully in diet formulation. Broiler chickens fed a diet containing high digestible soybean and MBM based on IDEA values performed better than those fed a diet containing lower digestible soybean meal and MBM.

Table 8. Performance of Broiler Chicks Fed Diets Varying in Predicted Lysine Digestibility from the Immobilized Digestive Enzyme Assay (IDEA)[1]

Diet description	21-d body weight (g)	21-d feed conversion
1. High digest SBM and MBM	763a	1.46a
2. High digest SBM:Low digest MBM	715b	1.49ab
3. Reg. digest SBM:high digest MBM	717b	1.47ab
4. Reg digest SBM:Low digest. MBM	693b	1.63b

[1]From Schasteen et al. (2003).
[2]IDEA predicted Lys digestibility (%) for the high digest. SBM, regular digest. SBM, high digest. MBM and low digest. MBM were 92, 89, 98 and 54%, respectively.

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