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METABOLIZABLE ENERGY OF MEAT AND BONE MEAL

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Primary Audience: Nutritionists, Quality Control Personnel, Renderers, Purchasing Agents

SUMMARY

Assaying meat and bone meal as separate fractions rather than complete meal yields substantially higher metabolizable energy (ME). Past research has indicated that elevated mineral levels in meat and bone meal depress the metabolizable energy of this ingredient under assay conditions. Samples of meat and bone meal from pork and from beef origin were separated into "bone" and "meat + fat" fractions by chloroform flotation. When meat + fat fractions were assayed and an ME value estimated for residual protein and fat in the bone fractions, the energy for samples of beef and of pork meat and bone meals used in this study were 2449 kcal/kg (1115 kcal/lb) and 2847 kcal/kg (1275 kcal/lb, respectively (94% DM).

Key words: Chloroform flotation, meat and bone meal, metabolizable energy
1997 J. Appl. Poultry Res. 6:169–173

DESCRIPTION OF PROBLEM

The metabolizable energy (ME) of meat and bone meal determined several decades ago and listed by the NRC [1] appears to be too low. Martosiswoyo and Jensen [2] discussed this question, noting that the level of inclusion of meat and bone meal in diets employed in ME assays may introduce artifacts into the determination. For example, the high levels of calcium and phosphorous resulting from a 40% rate of inclusion may compromise the utilization of other nutrients in meat and bone meal. These authors found an inverse relationship between level of dietary inclusion and resulting ME values. DeGroote and Keteles [3] and Dale [4] reached similar conclusions. Dolz and de Blas [5] reported a tendency toward a higher ME when meat and bone meal was included in the test diet at 6%, which approximates a practical level of usage.

A simple consideration of the energy contributions of the meat and the fat portions of meat and bone meal also suggests that a higher ME value is justified. Equations proposed by Titus [6] and Carpenter and Clegg [7] lend support to this view. In fact, a basic inconsistency is apparent in data for meat and bone meal listed by the NRC [1]. An ME of 2150 kcal/kg is assigned to a sample containing 50.4% protein and 10.0% ether extract (93% DM). Calculations employing a reasonable estimate of the ME of animal fat and the digestibility of amino acids in meat and bone meal from the same NRC publication yielded an ME approximately 25% higher than the published figure (Figure 1). A discrepancy of this magnitude clearly needs to be addressed.

If the minerals present in meat and bone meal interfere with the optimal digestion and absorption of fat and/or protein, assaying the meat + fat fraction separately could yield a more accurate assessment of ME. This study

- NRC listing for meat and bone meal:
  Metabolizable energy .... 2150 kcal/kg
  Crude protein 50.4%
  Ether extract 10.0%
  Dry matter 93.0%

- ME from 10% ether extract:
  7450 kcal/kg[A] x 0.10 = 745 kcal/kg

- ME from 50.4% crude protein:
  5300 kcal/kg[B] x 0.93 x 0.79 x 0.504 = 1962 kcal/kg

- Sum of ME from fat and protein = 2707 kcal/kg

FIGURE 1. Calculation of metabolizable energy (ME) of meat and bone meal based on compositional data from NRC [1] {[A]Table 9-9, NRC [1]; [B]Gross energy protein, dry matter basis [13] x 0.93 (% DM) x 0.79 (average digestbility of amino acids, NRC [1], Table 9-6) x 0.504 (% protein)}.

sought to compare the ME of meat and bone meals assayed as intact materials and as individual components.

Materials and Methods

Separation of materials by flotation in chloroform is a standard procedure of feed microscopists [8]. When this method is applied to meat and bone meal, most bone fragments sink to the bottom of the vessel, meat floats to the top, and fat is dissolved into the solvent. In each of two studies, 1 kg of beef meat and bone meal and 1 kg of pork meat and bone meal were thus fractionated by chloroform flotation. Chloroform was subsequently removed from the bone and meat+fat fractions by evaporation. The bone and meat+fat contents of each sample were weighed to determine percent composition. Proximate composition [9] and nitrogen-corrected true metabolizable energy (TME_n) [10, 11] was determined on each of the four original samples (two beef meal and two pork meal), as well as the four corresponding meat+fat fractions. The four bone samples were assayed for proximate composition and gross energy.

Because only small amounts of material can be separated by the flotation technique, it was considered impractical to conduct the standard apparent metabolizable energy (AME) procedure. As noted in the Results and Discussion section, however, the TME_n values obtained for whole meals, especially beef meal, agreed quite well with the NRC's AME value for meat and bone meal. Thus, even though the TME_n assay was employed in the present study (as only a small amount of each ingredient is required), the NRC value of 2150 kcal/kg seems appropriate as a point of reference.

The major objective of the study was to compare the metabolizable energy of meat and bone meals assayed with and without the high levels of minerals found in bone. As noted above, the TME_n of complete meals and of the meat+fat fractions was assayed directly. However, it was necessary to estimate the TME_n of bone fractions, as the mineral content of these was of course extremely elevated and could produce artifacts such as those described as resulting from an artificially high level of meat and bone meal inclusion. As noted in Table 1, the bone fractions had substantial gross energy values. Because the phosphorous in bone is considered completely available [12], it is reasonable to expect that the protein and fat components of bone are exposed to the digestive process well above respective sites of absorption. Employing the same energy and digestibility factors used in Figure 1 results in a reasonable estimate of the TME_n of the respective bone samples as 75% of gross energy.

Results and Discussion

Table 1 shows the proximate composition and gross energy of the original pork and beef meal samples, as well as the "meat+fat"

TABLE 1. Proximate composition and gross energy of meat and bone meals and of meat+fat (M+F) and bone fractions

	EXPERIMENT 1						EXPERIMENT 2					
	Beef			Pork			Beef			Pork		
	Meal	M+F	Bone	Meal	M+F	Bone	Meal	M+F	Bone	Meal	M+F	Bone
C Protein (%)	48.60	62.30	27.80	50.70	60.00	25.80	49.80	61.90	22.80	60.00	66.50	30.80
Fat (%)	10.30	16.40	1.60	8.80	10.60	2.40	9.70	15.60	1.70	9.60	12.20	1.90
Ash (%)	31.70	8.20	58.00	28.90	11.80	60.40	30.70	8.80	60.50	21.70	9.10	59.00
Moisture (%)	5.47	8.00	7.40	4.91	9.60	6.00	6.20	8.50	0.50	4.90	0.30	6.40
Gross Energy (kcal/g)	3.721	5.177	1.341	3.964	4.891	1.815	3.659	5.173	1.652	4.433	5.083	1.865

TABLE 2. Percentage composition of bone and meat+fat fractions of pork and beef meals

	EXPERIMENT 1		EXPERIMENT 2	
	Beef	Pork	Beef	Pork
Bone	44.9	32.0	44.5	22.1
Meat+Fat	55.1	68.0	55.5	77.9

and "bone" fractions. As expected, removing most of the bone by flotation increased levels of protein, fat, and gross energy and decreased percent ash. Table 2 lists the percentage of these fractions in the different samples. Although both experiments used beef meals of similar composition, the pork meal in Experiment 2 was much lower in ash and higher in protein than the sample used in the first study.

Table 3 shows the TME_n of meals and fractions in the two experiments. As expected, the TME_n of the meat+fat fractions was always substantially higher than that of the complete meal due to the removal of most of the bone. As noted above, the TME_n values for whole beef meals agree very well with those listed by the NRC, while pork meals show higher TME_n. These differences seem reasonable considering the lower percentage of bone in the pork meal samples (Table 2).

Table 4 illustrates the effect of assaying meat and bone meal by separate fractions as opposed to a complete meal. In the sample calculation, the determined TME_n of the meat+fat fraction is multiplied by the percent meat+fat in the respective sample. This is added to the estimated TME_n of bone, multiplied by the percent bone in the meal. These two results are added to obtain a TME_n for meat and bone meal independent of the confounding effects of high ash content. A consistent increase in energy was observed when meals were evaluated as separate fractions. Generally, the improvement was between 8 and 16%. However, the improvement in TME_n associated with the pork sample in Experiment 2 was considerably less. The ash content of this sample was particularly low (21.7%) as opposed to approximately 30% for the other three samples used in this study. It can be hypothesized that the TME_n obtained for the whole pork meal in Experiment 2 was less affected by high ash content than the other three.

Results obtained in this study agree closely with the theoretical calculation of ME for meat and bone meal outlined in Figure 1. These data support the hypothesis of Martosiswoyo and Jensen [2] that the metabolizable energy value of meat and bone meal is considerably higher than that reported in many tables of nutrient composition. Reducing the confounding effect of high levels of calcium and phosphorus can yield a more realistic estimate of the digestibility of the meat and fat components. Results of the present study confirm previous results from this laboratory [4], in which increases in TME_n values for meat and bone meal were observed when the ingredient was evaluated at a 10% level of inclusion. At this rate of inclusion, calcium and phosphorus levels would not be excessive. In industry practice, meat and bone meals are not generally employed in poultry diets at a level to provide excessive calcium and phosphorus. These results suggest that when adjusting a nutrient matrix in preparation for practical feed formulation, it is appropriate to assign a higher value to meat and bone meal than would be obtained through routine AME_n or TME_n assays.

TABLE 3. TME_n of original meat and bone meal (meal) samples, and of meat+fat (M+F) fractions (as is basis)

	EXPERIMENT 1				EXPERIMENT 2			
	Beef		Pork		Beef		Pork	
	Meal	M+F	Meal	M+F	Meal	M+F	Meal	M+F
Kcal/kg	2138	3377	2336	3291	2224	2589	2966	3557

TABLE 4. Sample calculation of adjusted TME_n of meat and bone meal, and corresponding results of Experiments 1 and 2

SAMPLE CALCULATION: BEEF MEAL, EXPERIMENT 1

TME_n Whole Meal (Table 3) = 2138 kcal/kg

TME_n M+F (Table 3) = 3377 x 0.551[A] = 1861 kcal/kg

TME_n Bone = 1006[B] x 0.449[A] = 452 kcal/kg

Sum of fractions = 2313 kcal/kg

	EXPERIMENT 1		EXPERIMENT 2		AVERAGE	
	Beef	Pork	Beef	Pork	Beef	Pork
TME_n (kcal/kg) of complete meal	2138	2336	2224	2966	2181	2651
TME_n (kcal/kg) of sum of fractions	2313	2674	2596	3080	2455	2877
Improvement	+8.2%	+14.5%	+16.7%	+3.8%	+12.5%	+8.5%

[A]Table 2

[B]Gross energy of bone (Table 1) x 0.75 (assumed digestibility, see text)

Conclusions and Applications

1. The value for ME listed by the NRC for meat and bone meal (2150 kcal/kg, 980 kcal/lb) was generally confirmed in TME_n tests only when assayed with levels of bone (*i.e.*, calcium and phosphorus) higher than found in practical diets.
2. Pork and beef meals showed consistently higher TME_n when meat+fat fractions were assayed separately. This suggests that for practical formulation energy values of 2450 kcal/kg (1115 kcal/lb) should be employed for meat and bone meals of beef origin and 2800 kcal/kg (1275 kcal/lb) for pork. For mixed meals of uncertain origin, an intermediate value can be estimated on the basis of fat, ash, and (if known) gross energy.

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ACKNOWLEDGEMENT

The assistance of Mr. Steve Thomas of Griffin Industries and Dr. Gerardo Penalva of Bachoro S.A. de C.V. in obtaining samples is sincerely appreciated.