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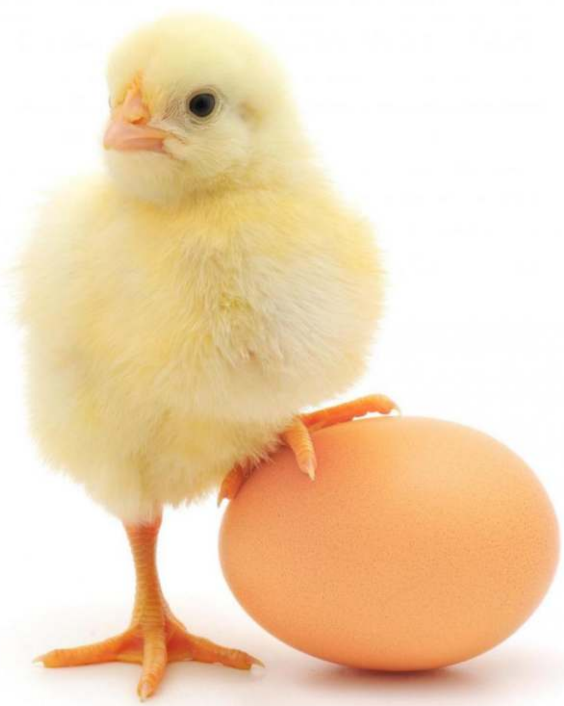

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Evaluation of the Metabolizable Energy of Poultry By-Product Meal for Chickens and Turkeys by Various Methods

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Abstract: The available energy of several poultry by-product meal products were determined by various experimental methods. It is imperative to determine the accurate available energy value for these products for proper diet formulation and product usage. Leghorn roosters and turkeys were tube fed the products for the assay based on the True Metabolizable Energy (TME) system. Three week old battery reared chicks and poults were fed each product as 50% of a basal diet. The birds were fed for three days with total consumption and excreta measured. Apparent Metabolizable Energy (AME) was then calculated. Endogenous pens were included to make adjustments for AME. Lastly, ileal contents of the chicks and poults were collected to determine ileal AME. There were few differences in assay methodologies noted. Significantly different ME values among assay techniques were found in only four of 15 products. The variable nature of poultry by-product meal led to significant differences in mean ME values among products. There was no difference between pooled AME and TME values, or species. It appears that the TME values commonly determined with Leghorn roosters is acceptable for broilers and turkeys. An effort was made to develop an equation that could predict the TME value of a poultry by-product meal product given the proximate analysis and mineral composition. The first equation, using proximate and mineral data, was inadequate with an R^2 = 0.11. Adding the gross energy as a predictor variable greatly improved the effectiveness of the prediction equation (R^2 = 0.98).

Key words: Metabolizable energy, poultry by-product meal, prediction equation, turkeys

Introduction

A feedstuff readily available for poultry rations is poultry by-product meal. It is usually composed of the wastage from poultry meat processing. While typically higher in protein content and lower in mineral levels, poultry by-product meal also suffers the same variability found in meat and bone meal. This is largely due to the inclusion of other tissues, such as feathers, and differences in rendering procedures (Elkin, 2002).

Poultry by-product meal may be a more desirable product if an accurate metabolizable energy value can be readily determined. Most energy values are based on Leghorn rooster evaluations, while species differences have been shown (Farhat *et al.*, 1998; Ostrowski-Meissner, 1984). Employing both chickens and turkeys, it was the objective of this study to determine the metabolizable energy availability of several poultry by-product meals using the true metabolizable energy (TME) system and both ileal and excreta ME measurements, with an adjustment for endogenous loss. The proximate analysis, mineral composition, gross energy of the feedstuff, and the nitrogen corrected TME (TME_n) were used in an effort to develop an equation that nutritionists could use to rapidly determine the nutritive value of a poultry by-product meal product.

Materials and Methods

Fifteen poultry by-product meals were obtained through commercial sources. The proximate and mineral composition of each sample was determined (AOAC, 1970). The available energy of each product was established by each of four assays for both species, a 2 x 4 factorial design. The first assay was based on Sibbald's TME system (1986). Modifications were made for cecectomized roosters and intact turkeys. For both species, birds were not allowed feed for 36 hours. This was to ensure adequate clearing of the gastrointestinal tract. After the feed withdraw, the birds were tube fed a measured quantity of product and placed in metabolism cages. Roosters received 30 grams and turkeys received 75 grams of a poultry by-product meal. Each product was replicated eight times as well as eight replications for endogenous collection. Excreta were collected for 48 hours. The excreta were then dried at 60°C in a forced air oven and weighed. The gross energy of the feed and the excreta content were determined via bomb calorimetry. Nitrogen content of feed and excreta were also determined by LECO analysis (AOAC Method 990.03) for nitrogen correction. An example of the calculation for TME_n follows:

$$TME_n = GE_{n\ feed} - GE_{n\ fed\ excreta} + GE_{n\ fasted\ excreta}$$

Where the GE_n of the excreta from fasted birds was used to correct for endogenous loss. Excreta were nitrogen corrected to maintain a zero nitrogen balance offset from fasting and yield a TME_n value.

Table 1: Composition of Basal Diet[1] for Chicks and Poults

Ingredients	Basal Diet %
Ground Corn	74.105
Soybean Meal (48%)	21.79
Dicalcium Phosphate	1.813
Limestone	1.485
Salt	0.25
DL-Methionine	0.009
Trace Mineral Premix[2]	0.1
Vitamin Premix[3]	0.075
Selenium Premix[4]	0.03
Choline Chloride	0.182
Copper Sulfate	0.013
Coban	0.075
Chromic Oxide	0.1

[1]Diluted to 50% with addition of PM sample for ME assay. [2]Trace mineral premix analysis: Ca 2.50%, Fe 6.0%, Mg 2.68%, Mn 11.0%, Zn 11.0%, I 2,000 ppm. [3]Vitamin premix provided per kilogram of diet: Vitamin A 1,500 IU, D 200 IU, E 10 IU, K 2 mg, Thiamin 1.8 mg, Riboflavin 4.5 mg, Pyridoxine 3.5 mg, Folic acid 0.55 mg, Niacin 35 mg, Pantothenic acid 14 mg, Choline 1,300 mg. [4]Selenium premix analysis: Ca 36.08%, Se 0.06%.

The second two assays were designed based on the ME system of Anderson *et al.* (1958) to determine the nitrogen corrected apparent metabolizable energy (AME_n) and AME adjusted for endogenous loss ($aAME_n$) via battery studies. In poultry species, an AME value is calculated by subtracting the gross energy of the excreta from the gross energy of the feed (NRC, 1994). Five-hundred and ten commercial strain broilers and 510 commercial turkey hens were obtained at the day of hatch and reared to 24 days of age. A basal diet was calculated (Table 1) to meet all nutritional needs recommended by the National Research Council (1994). Chicks and poults were reared in multi-tiered wire floor batteries. They were allowed access to feed and water *ad libitum* with constant lighting. There were five birds placed in each battery pen. Dietary treatments were made by diluting the basal diet with the addition of each product at 50%. The 24 hours prior to the start of the assay, feed was removed to allow time for clearing of the gastrointestinal tract. On day 21, birds were allocated to pens at random and treatments were assigned via a random number table. There were six replicate pens per treatment plus another six pens receiving the basal diet. Six pens were withheld from feed while the total excreta was collected to serve for endogenous measurements. Total feed intake and total excreta for all pens were measured. Feed and excreta were also nitrogen corrected for uniformity. The trial was conducted at 24 days of age. The AME_n and $aAME_n$ were calculated as follows:

$$AME_n = GE_{n\ feed} - GE_{n\ fed\ excreta}$$
$$aAME_n = GE_{n\ feed} - GE_{n\ fed\ excreta} + GE_{n\ fasted\ excreta}$$

The energy determinations of feed and excreta were adjusted for the basal diet energy contribution in a manner suggested by Sibbald and Slinger (1963). Briefly, the ME of the basal diet accounted for half of the ME of each treatment. The ME of each product was then calculated.

The fourth assay was based on ileal collection in determining AME. At the end of the trial, the chicks and poults were euthanized by cardiac puncture with a sodium phenobarbital solution to prevent movement of digesta in the gut. A sodium phenobarbital solution depresses the central nervous system and therefore intestinal contractions (Barnhart, 1990). The contents of the ileum were collected from Meckel's diverticulum to the ileocolic juncture. Meckel's diverticulum was chosen because it is considered the end of the jejunum and the start of the ileum. Most digestion and absorption of carbohydrates, proteins, and fats occur in the duodenum and jejunum. Microbial fermentation occurs after exiting the ileum. Therefore, ileal contents should provide an adequate measure of metabolizability of a product (Scanes et al., 2004). Chromic oxide was added at 0.05% of the diet as a marker. All samples were pooled by pens. Feed and digesta were also nitrogen corrected for uniformity. The following equation was used to determine AME_n:

$$AME_n = GE_{n\ diet} - [GE_{n\ digesta} \times (Marker_{diet}/Marker_{digesta})]$$

Analysis of variance was conducted on assay methods for each product, pooled AME_n and TME_n values, pooled chicken and turkey values, and pooled digesta and excreta values. A Tukey-Kramer test was used to determine differences in means when appropriate. The level of significance was set at 0.05.

Once all data were compiled (Table 2 and 3), a multiple regression equation was used for prediction of the TME_n value of a poultry by-product meal given the nutrient composition. Crude protein (CP), moisture, ash, fat, carbohydrates (CHO), gross energy (GE), calcium (Ca), phosphorus (P), sodium (Na), potassium (K), and iron (Fe) were used as predictor variables. Stepwise regression was used to determine which predictor variables were significant for a prediction equation. All data were analyzed with the JMP version of SAS.

All procedures complied with the laboratory's Standard Operating Procedures and the University of Missouri's Animal Care and Use guidelines.

Results and Discussion

Overall, the ME values of poultry by-product meal products appear in line with the recommendation of the National Research Council (1994), with a TME_n of 3,120 kcal/kg. There were few differences in methodology for determining metabolizable energy. Only four of the 15

Table 2: Proximate and Mineral Composition of Poultry By-product Meal Products

Sample	CP %	Moisture %	Ash %	Fat %	Ca %	CHO %	P %	K %	Na %	Fe ppm	GE Kcal/kg
pm-2	52.88	7.62	22.15	12.55	7.74	4.8	2.91	0.64	0.55	1,244	4,636
pm-4	66.88	9	10.18	10.85	1.98	3.09	1.48	0.77	0.47	672	5,142
pm-5	66.57	5.39	11.33	12.87	3.05	3.84	1.97	0.66	0.5	854	4,945
pm-6	65.32	8.17	12.33	11.78	3.05	2.4	2.05	0.69	0.48	447	5,156
pm-8	68	3	11	12.5	*	*	*	*	*	*	3,760
pm-9	63.13	7.93	17.52	10.48	5.44	0.94	2.61	0.6	0.88	545	4,033
pm-10	62.05	6.3	19.28	11.23	6.21	1.14	3.19	0.61	0.52	239	4,529
pm-11	58.22	4.22	28	9.53	9.53	0.03	4.8	0.42	0.71	142	4,020
pm-12	67.5	6.28	12.27	12.17	3.17	1.78	2.11	0.86	0.6	175	5,215
pm-14	69.07	6.9	13.03	9.89	3.67	1.11	2.28	0.8	0.49	151	4,533
pm-15	66.26	4.57	16.34	11.34	5	1.49	2.87	0.83	0.48	367	4,930
pm-16	67.5	4.28	19.58	9.02	6.02	0	3.29	0.69	0.53	167	4,348
pm-17	60.41	6.5	20.4	11.01	6.71	1.68	3.33	0.7	0.59	399	4,640
pm-18	58.13	7.94	17.41	17.41	5.46	3.59	2.31	0.59	0.49	1,592	4,860

*Data unavailable.

Table 3: Mean Metabolizable Energy Values for each Assay Method of each Poultry By-product Meal Product (kcal/kg)

Sample	pm-2		pm-4		pm-5		pm-6	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TMEn	3,492[a]	127	2,123[a]	113	2,944[abc]	109	2,188[a]	69
Turkey TMEn	2,971[b]	412	2,454[a]	113	2,604[c]	109	2,054[a]	69
Chick Digesta AMEn	2,956[b]	127	2,333[a]	113	3,059[abc]	98	2,128[a]	69
Chick Excreta AMEn	2,939[b]	127	2,476[a]	113	3,171[ab]	98	2,221[a]	69
Chick Excreta aAMEn	2,980[b]	127	2,515[a]	113	3,203[a]	98	2,258[a]	69
Poult Digesta AMEn	2,973[b]	127	2,197[a]	126	2,706[abc]	109	1,957[a]	90
Poult Excreta AMEn	3,191[ab]	127	2,167[a]	113	3,072[abc]	98	2,185[a]	69
Poult Excreta aAMEn	3,214[ab]	127	2,201[a]	113	3,091[ab]	98	2,206[a]	69
Significance	0.0464		NS		0.0024		NS	

	Pm-7		pm-8		pm-9		pm-10	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TMEn	2,972[a]	101	1,980[a]	121	2,734[a]	168	2,944[a]	93
Turkey TMEn	2,813[a]	113	2,348[a]	109	2,219[a]	168	3,163[a]	84
Chick Digesta AMEn	2,789[a]	101	2,384[a]	109	1,971[a]	168	2,887[a]	84
Chick Excreta AMEn	2,836[a]	101	2,434[a]	109	2,403[a]	168	3,105[a]	84
Chick Excreta aAMEn	2,889[a]	101	2,473[a]	109	2,444[a]	168	3,145[a]	84
Poult Digesta AMEn	2,614[a]	101	2,457[a]	121	2,264[a]	168	2,860[a]	84
Poult Excreta AMEn	2,658[a]	101	2,224[a]	109	2,499[a]	168	2,915[a]	84
Poult Excreta aAMEn	2,677[a]	101	2,244[a]	109	2,527[a]	168	2,938[a]	84
Significance	NS		NS		NS		NS	

	pm-11		pm-12		pm-14		pm-15	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TMEn	2,605[a]	114	2,536[a]	167	3,111[a]	73	1,772c	106
Turkey TMEn	2,614[a]	114	2,726[a]	167	3,104[a]	73	1,869bc	106
Chick Digesta AMEn	2,381[a]	114	2,727[a]	167	3,011[a]	73	1,778bc	168
Chick Excreta AMEn	2,658[a]	114	2,469[a]	167	3,135[a]	73	2,113ab	106
Chick Excreta aAMEn	2,700[a]	114	2,520[a]	167	3,180[a]	73	2,156ab	106
Poult Digesta AMEn	2,433[a]	114	2,369[a]	167	3,147[a]	82	2,246a	119
Poult Excreta AMEn	2,382[a]	114	2,567[a]	167	3,325[a]	82	1,895bc	106
Poult Excreta aAMEn	2,408[a]	114	2,586[a]	167	3,245[a]	82	1,936abc	106
Significance	NS		NS		NS		0.0491	

			Pm-15		pm-17		pm-18	
			Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TMEn			2,462[a]	124	3,331[a]	82	3,192[a]	94
Turkey TMEn			2,662[a]	110	3,014[a]	82	2,791[b]	109
Chick Digesta AMEn			2,655[a]	110	3,119[a]	82	2,838[b]	84
Chick Excreta AMEn			2,764[a]	110	3,197[a]	82	3,099[a]	84
Chick Excreta aAME			2,811[a]	110	3,239[a]	82	3,141[a]	84
Poult Digesta AMEn			2,768[a]	110	3,142[a]	82	3,045[ab]	94
Poult Excreta AMEn			2,786[a]	110	3,099[a]	82	3,212[a]	84
Poult Excreta aAME			2,807[a]	110	3,122[a]	82	3,238[a]	84
Significance			NS		NS	NS	0.0104	

[1]Means within columns with no common letter are significantly different.

[2]Pooled std error differs due to unequal number of experimental units.

Table 4: Mean Metabolizable Energy Comparisons for Poultry by-product Meal Products (kcal/kg)

System	Mean[1]	SE[2]	Significance
ME[3]	2,679[a]	23	NS
TME[3]	2,643[a]	41	
Collection	Mean[1]	SE[2]	Significance
Digesta[4]	2,603[b]	40	P<0.05
Excreta[4]	2,718[a]	28	
Total[4]	2,643[ab]	41	
Species	Mean[1]	SE[2]	Significance
Chicken	2,690[a]	28.6	NS
Turkey	2,651[a]	28.8	

[1]Means with no common letter are significantly different.
[2]Standard error differs due to unequal number of experimental units. [3]ME System refers to battery reared birds and TME System refers to tube fed birds. [4]Digesta and excreta samples were collected from battery reared birds and total samples were collected from tube fed birds.

Table 5: Mean Metabolizable Energy Values for each Poultry By-product Meal Product (kcal/kg)

PM Sample	Mean[1,3]	SE[2]
2	3092[a]	47
4	2287[gh]	47
5	3027[a]	48
6	2109[hi]	47
7	2780[bc]	47
8	2326[fgh]	47
9	2383[efg]	47
10	2996[ab]	47
11	2523[def]	47
12	2562[cde]	47
14	3170[a]	48
15	1907[i]	47
16	2721[cd]	47
17	3158[a]	47
18	3085[a]	48
Significance	<0.0001	

[1]Means with no common letter are significantly different.
[2]Standard error differs due to unequal number of experimental units. [3]Mean is of all replicates of all methods for each sample.

products resulted in significantly different ME values among methods. Of those four, two were nearly insignificant. There were no consistent differences in methodologies among products, (Table 3). Other values were relatively consistent. These results indicate that any methodology used to determine the ME of a poultry by-product meal will yield similar values.

There appears to be no difference between the battery ME System of Anderson *et al.* (1958) and Sibbald's TME System (1986) (Table 4). This would indicate that tube feeding may be in used place of battery trials and still obtain similar results. Dale and Fuller (1982) found that TME values are an adequate measure of metabolizable energy values. The TME System has the advantage of being less expensive to conduct, using less feed, fewer animals, and taking much less time.

There were also no differences in the ME values among collection methods. Ileal contents provided similar values as excreta (Table 4). However, there is some question as to the reliability of some marker methods (Schneider and Flatt, 1975; National Research Council, 1994; Scott and Boldaji, 1997; Scott and Hall, 1998). There were differences in the average ME values among poultry by-product meal products (Table 5). This is undoubtedly due to differences in nutrient composition, reinforcing the variability of the feedstuff (Table 2). As with meat and bone meal, a variety of tissues may compose the final rendered product. Poultry by-product meals may be composed of offal, carcasses, feathers, or a combination of tissues.

One of the important goals of these experiments was to find differences between chickens and turkeys. The data revealed no differences between the pooled ME values of chickens and turkeys (Table 4). This indicated that the values commonly found for chickens, and Leghorn roosters in particular, can be applied to broilers and turkeys as well. Dale and Fuller (1980) found a similar agreement among roosters, broilers, and turkeys.

The ME_n values from this trial were similar to the National Research Council's (1994) suggestion of 3,120 kcal/kg. Others have found varying results. Pesti *et al.* (1986) determined the average TME_n value of poultry by-product meal to be 3,920 kcal/kg with a standard error of 70 kcal/kg. Han and Parsons (1990) found TME_n values between 2,863 and 3,390 kcal/kg. Dale *et al.* (1993) found a TME_n range between 3,626 and 5,247 kcal/kg for poultry offal meals. Dale (1992) also found TME_n values ranging from 3,092 to 3,996 kcal/kg for feather meals.

The development of a prediction equation based on proximate and mineral analysis was unsuccessful. The best equation for poultry by-product meal yielded an R^2=0.11, with crude protein being the only significant variable (Fig. 1). The equation generated was as follows:

$$TME_n = 4491.3 - 28.1*(CP) \quad (R^2 = 0.11)$$

Using gross energy greatly improved the accuracy of the prediction equations. The R^2 to 0.98 (Fig. 2):

$$TME_n = -2486.0 + 71.2*(Moisture) + 0.9*(GE) - 0.2*(Fe) + 67.7*(Ca) + 1036.7*(K) \quad (R^2 = 0.98)$$

Dale (1992) developed an equation for feather meal with an R^2 value of 0.81, and Dale *et al.* (1993) obtained an R^2 value of 0.81 in predicting the TME_n value of poultry offal meal. Pesti *et al.* (1986) found an R^2 value of 0.93 for poultry by-product meal. However, this trial examined nearly twice as many products. Pesti *et al.* (1986) has fewer data points to fit a line to by analyzing fewer samples. While this may improve the R^2 value, it is difficult to achieve the same variability seen in commercial meals.

Protein quality may be a large factor in the variability of a poultry by-product meal. Since poultry by-product meal is approximately 60% protein, a large portion of the

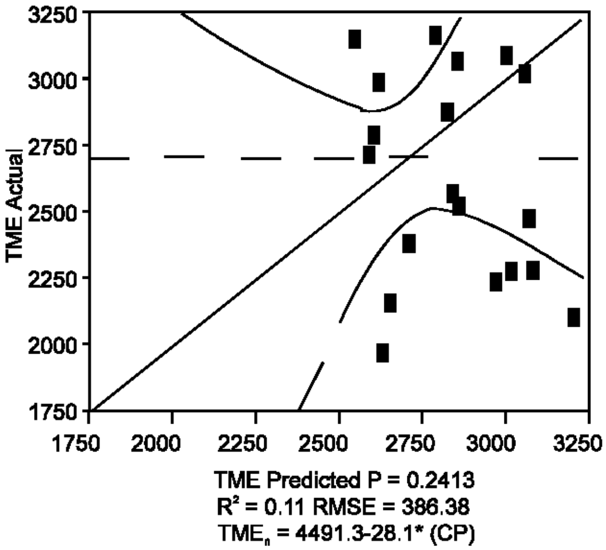

Fig. 1: Best-Fit Prediction Equation of TMEn Value of Poultry By-product Meal from Proximate Analysis

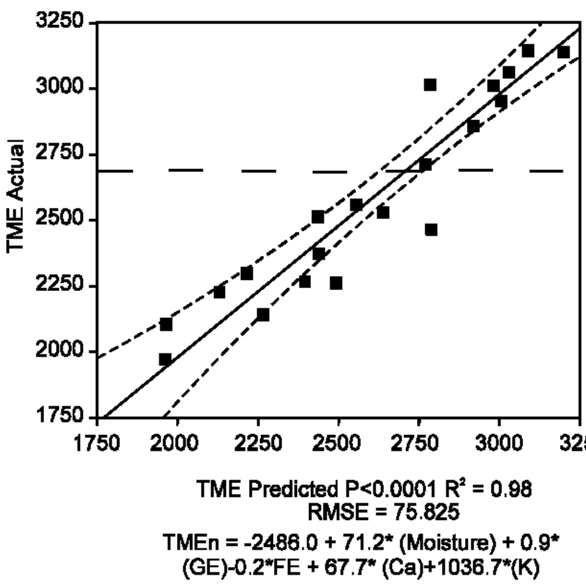

Fig. 2: Best-Fit Prediction Equation of TMEn Value of Poultry By-product Meal from Proximate Analysis and Gross Energy

available energy comes from protein. If the protein content of the product is not readily digested, such as that from feathers, the available energy will be less than that of a product with higher quality protein. Therefore, two products may have the same amount of protein, but differing amounts of available energy. This problem complicates the development of a useful prediction equation.

The fact that the GE improved predictions is not surprising since GE is the basis of the TME_n calculation. Relatively few laboratories have the equipment to determine energy and proximate analysis does not determine gross energy, making it an impractical component of the equation for nutritionists. When left with only the proximate and mineral composition, the products appear too variable to accurately predict the TME_n.

These equations suggest that it may be worthwhile for nutritionists to invest in bomb calorimetry equipment. The determination of the gross energy of a feedstuff is rapid, each sample taking only a few minutes. A prediction equation, utilizing the gross energy of the product and the proximate and mineral composition can calculate the TME_n of the product. This equation does indicate that the use of animals may not be needed, saving both time and money.

Acknowledgements

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References

Anderson, D.L., F.W. Hill and R. Renner, 1958. Studies of the metabolizable and productive energy of glucose for the growing chick. J. Nutr., 65: 561-574.

Association of Official Analytical Chemists, 1970. Official Methods of Analysis. Association of Official Analytical Chemists. Washington, D.C.

Barnhart, E.R., 1990. Physicians' Desk Reference, 44th ed. Medical Economics Company. Oradell, New Jersey.

Dale, N., 1992. True metabolizable energy of feather meal. J. Appl. Poultry Res., 1: 331-334.

Dale, N.M. and H.L. Fuller, 1980. Additivity of true metabolizable energy values as measured with roosters, broiler chicks, and poults. Poult. Sci., 59: 1941-1942.

Dale, N.M. and H.L. Fuller, 1982. Applicability of the true metabolizable energy system in practical feed formulation. Poultry Sci., 61: 351-356.

Dale, N., B. Fancher, M. Zumbado and A. Villacres, 1993. Metabolizable energy content of poultry offal meal. J. Appl. Poult. Res., 2: 40-42.

Elkin, R.G., 2002. Nutritional components of feedstuffs: a qualitative chemical appraisal of protein. In: Poultry Feedstuffs: Supply, Composition and Nutritive Value. CAB International. Wallingford. UK.

Farhat, A., L. Normand, E.R. Chavez and S.P. Touchburn, 1998. Nutrient digestibility in food waste ingredients for Pekin and Muscovy ducks. Poult. Sci., 77: 1373-1376.

Han, Y. and C.M. Parsons, 1990. Determination of available amino acids and energy in alfalfa meal, feather meal, and poultry by-product meal by various methods. Poult. Sci., 69: 1544-1552.

National Research Council, 1994. Nutrient Requirements of Poultry, 9th Rev. Ed. National Academy Press. Washington, D.C.

Ostrowski-Meissner, H.T., 1984. Effect of contamination of foods by *Aspergillus flavus* on the nutritive value of protein. J. Sci. Food Agri., 35: 47-58.

Pesti, G.M., L.O. Faust, H.L. Fuller, N.M. Dale and F.H. Benoff, 1986. Nutritive value of poultry by-product meal. 1. Metabolizable energy values as influenced by method of determination and level of substitution. Poult. Sci., 65: 2258-2267.

Scanes, C.G., G. Brant and M.E. Ensminger, 2004. Poultry Science, 4th ed. Pearson Prentice Hall. Upper Saddle River, New Jersey.

Schneider, B.H. and W.P. Flatt, 1975. The Evaluation of Feeds through Digestibility Experiments. The University of Georgia Press. Athens, Georgia.

Scott, T.A. and F. Boldaji, 1997. Comparison of inert markers [chromic oxide or insoluble ash (Celite™)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poult. Sci., 76: 594-598.

Scott, T.A. and J.W. Hall, 1998. Using acid insoluble ash marker ratios (diet:digesta) to predict digestibility of wheat and barley metabolizable energy and nitrogen retention in broiler chicks. Poult. Sci., 77: 674-679.

Sibbald, I.R., 1986. The TME system of feed evaluation: methodology, feed composition data and bibliography. Tech. Bull. 1986-4E. Ottawa, Canada: Agriculture Canada.

Sibbald, I.R. and S.J. Slinger, 1963. A biological assay for metabolizable energy in poultry feed ingredients together with findings, which demonstrate some of the problems associated with the evaluation of fats. Poult. Sci., 42: 313-325.