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THE VALUE OF ANIMAL PROTEIN SUPPLEMENTS IN POULTRY RATIONS

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INTRODUCTION

The Importance of Balanced Rations

Since the cost of feed represents the greatest part of the total cost of production of meat, milk and eggs, the greatest opportunity for increased economy of production can occur by providing well balanced rations. When the ration is properly balanced with regard to energy and nutrients the amount of feed eaten will generally determine the rate of growth or production within the genetic capability of the animal. The greatest feed efficiency will also be realized when the ration is properly balanced. This is especially true with poultry and swine which are so completely dependent upon the quality of the feed provided.

The first and greatest requirement of the animal is for ENERGY. Energy is the fuel which runs the metabolic machinery of the body and keeps the animal alive and working. Thus: ANIMALS EAT PRIMARILY TO SATISFY THEIR ENERGY NEEDS. It follows, THEREFORE, THAT ALL NUTRIENTS MUST BE PROVIDED IN PROPORTION TO THE ENERGY LEVEL OF RATION. When the animal has consumed enough feed to satisfy its energy needs, that amount of feed must contain all necessary nutrients in the proper balance and at the required level. That is the underlying principle of modern feed formulation.

A balanced diet must contain proteins to supply the necessary AMINO ACIDS. Some of the amino acids can be synthesized by the animal provided there is adequate amount of protein present. Some cannot be synthesized *de novo* and must be provided, as such, either as components of the natural ingredients or in synthetic form. The amount and proportions of these ESSENTIAL AMINO ACIDS and their availability is a measure of the quality of the protein supplements to be used in the ration. The amino acids most limiting in common feed ingredients are lysine and the sulfur-containing amino acids, methionine and cystine. Blood meal is one of the richest sources of lysine, and feather meal is the richest source of cystine available to the feed industry.

A balanced diet must also contain ESSENTIAL FATTY ACIDS, VITAMINS and MINERALS. Meat and bone meal and poultry by-product meal are rich sources not only of calcium and phosphorous but also of the trace elements which are a vital part of the mineral requirements of animals.

The nutrient requirements of animals are quite well established. They are published in the National Research Council Recommended Nutrient Allowances and in a number of other nutrition texts and guides.

Average analyses of the various feed ingredients can also be found in similar publications; however, the nutrient composition of the feed ingredients is not constant. Agronomists are continually giving us new strains or varieties of the grains which are culturally more adaptable to the various regions of the world. Similarly, with those feed ingredients which are classified as by-products, new methods of processing and new sources of raw materials result in continual upgrading of the quality of products available. It is the purpose of this publication to provide the nutritionist with the latest findings in the nutritional values of animal by-product supplements, including meat and bone meal, poultry by-product meal, feather meal and blood meal for use in poultry rations.

Animal Protein Supplements

Meat and bone meal, blood meal, poultry by-product meal, hydrolyzed poultry feathers and feed grade animal fat are produced by the rendering industry. The raw materials of this industry consist largely of by-products from the meat packing and processing industries and trimmings from retail stores, restaurants, and other establishments handling meats. The rendering operations perform a very important function by recycling inedible tissues of poultry and other animals into nutritious products that are valuable feed ingredients for livestock, poultry and pets. The proteins and minerals in the animal by-products help fill the need for essential nutrients while the fat provides energy in the most concentrated form available for use in feeds. Composition of the various animal protein supplements is shown in Table 1 for those nutrients which are routinely calculated by the nutritionist and which will be significantly influenced by the protein supplements. More complete nutrient composition of these products in shown in the Appendix. Values for soybean meal (dehulled) are also shown for comparative purposes, as are the NRC nutrient requirements of broilers (0-3 wks of age).

The acceptance or rejection of renderer products, the amount to be used and the acceptable price will depend upon the nutritional values entered into the computer program of the nutritionist. This presents a challenge both to the renderer and to the Fats and Proteins Research Foundation. It behooves the renderer to produce a high quality product that consistently equals or exceeds the "average" values found in analysis tables used by the feed industry. Moreover, he must convince the potential user of these values and their reliability.

The challenge for the FPRF is to establish realistic values that accurately describe the majority of the animal by-products produced by the rendering industry. Judicious selection of credible researchers with sound research projects will go a long way toward establishing these values and disseminating them to a critical feed industry. This has been and will be a continuing effort of FPRF.

Table 1. Nutrient composition of animal by-products, soybean meal and nutrient requirements of broilers[1,2]

Component	Meat & bone meal	Poultry by-prod. meal	Blood meal[3]	Feather meal	Soybean meal	NRC Req. (Broilers: 0-3 wks)
Metabolizable energy (kcal/kg)	2444[4]	3300[4]	3420	3073[5]	2530	3200
Crude protein (%)	50	65.1	88.9	86.4	48.5	23
Fat (%)	8.6	13.0	1.0	3.3	1.0	--
Moisture (%)	7.0	7.0	7.0	7.0	10.0	--
Calcium (%)	10.1	3.0	0.3	0.33	0.27	1.0
Phosphorus avail. (%)	5.0	1.7	0.25	0.55	0.2	0.45
Pepsin digestibility (%)	91.8	90.0	95.6	87.0	90.0	
<u>Amino acids</u> (%)						
Arginine	3.6	4.0	3.8	5.4	3.7	1.44
Lysine	2.6	2.7	8.9	1.7	3.1	1.20
Methionine	0.7	1.0	1.5	0.4	0.7	0.50
Cystine	0.3	0.7	1.5	4.0	0.7	--
Meth + Cys	1.0	1.7	3.0	4.4	1.4	0.93
Tryptophan	0.3	0.5	1.1	0.5	0.7	0.23

[1] Values from National Research Council (1984) except as noted.

[2] "As fed" basis.

[3] Spray or ring dried.

[4] Estimated from Martosiswoyo and Jensen (1987).

[5] Fuller and Dale (1986)

MEAT AND BONE MEAL

Meat and bone meal (MBM) has been used as a protein supplement in feeds longer than any other protein supplement with the possible exception of skim milk. Tankage, as the forerunner of the modern meat and bone meal, was used as a supplement in swine feeds around the turn of the century. In nutrition experiments conducted throughout the first half of this century animal proteins invariably proved to be superior to vegetable proteins in promoting the growth and production of animals. This superiority was considered to be inherent in the protein itself and animal proteins were considered indispensable for all monogastric animals. In recent years the characterization of proteins on the basis of their amino acid content, the discovery of vitamin B_{12} and its identity with the "animal protein factor" and the discovery of the essential nature of certain trace elements have removed much of the mystery of the various protein concentrates and have placed their nutritional attributes on a sound quantitative basis (Fuller and Wilder, 1987).

Wilder (1956) was one of the first to demonstrate the extent to which MBM could be used in broiler rations using constraints of modern feed formulation. He fed levels of MBM from 0-20% of the ration replacing soybean meal. Energy, protein, calcium and phosphorous were kept constant in all rations. In the first test 8% MBM gave optimum results with only a slight reduction in performance when levels were increased to 17%. All levels of MBM below 20% gave significantly better growth and feed efficiency than the soybean meal control. In the second trial optimal results were obtained at the 14% level of inclusion.

These results are typical of results obtained in the intervening years. More recently at the University of Georgia, Jensen (1983) substituted levels of MBM from 5%-40% in a corn-soy basal ration maintaining constant levels of energy and all major nutrients (Table 2). Results demonstrated that the performance of broilers fed 10% MBM were at least equal to those receiving the corn-soy basal ration.

Table 2. Effect of level of MBM on chick growth and feed conversion (Jensen, 1983)

Level of MBM	Body wt. at 3 weeks	Feed/Gain
(% of ration)	(g)	
0[1]	503	1.52
5	529	1.52
10	515	1.53
20	474	1.64
30	484	1.69
40	484	1.75

[1] Corn-soy basal ration. Substitution of meat and bone meal calculated to keep energy and protein equal in all rations.

Since MBM is being used extensively in poultry rations the problem is not when and how much to use or even at what price. When the appropriate nutritional attributes are assigned to it the computer will make all necessary comparisons and decide to use it or reject it and assign an appropriate opportunity price.

Metabolizable Energy Value of Meat and Bone Meal

Based upon results obtained over the years it has been suspected that the energy value of meat and bone meal as listed by the National Research Council (1960 kcal/kg) is far below the actual energy value for this product. This underestimation would result in calorie:protein ratios wider than intended in feed formulas and would contribute to the deposition of excess fat in the carcass of broilers. This is currently a serious problem in broiler production all over the world. Furthermore, underestimation of the ME value would greatly reduce the opportunity price of MBM in least cost feed formulation. Classical metabolizable energy determinations are made by substitution. In order to reduce the errors from extrapolating from small levels of substitution it is customary to use as much as 40% of the test ingredient in the determination. Yet such a level of substitution is not applicable to practical feeding conditions. In 3 experiments conducted at the University of Georgia, it was found that when the level of substitution was reduced from 40% to 20% the metabolizable energy value increased from an average of 2130 to about 2560 kcal/kg (Martosiswoyo and Jensen, 1987).

To carry this a step further, they fed three broiler rations containing 10% meat and bone meal all from the same sample but with assigned values ranging fom 1960 to 2500 kcal/kg (Table 3). The rations were calculated to be isocaloric on the basis of these assigned values for the meat and bone meal. Thus, less added fat was required at each successive increase in the assigned value for the meat and bone meal in order to achieve the same calculated energy level for all rations. Note that when the "book" value of 1960 kcal/kg (NRC, 1984) was used, carcass fat was increased significantly indicating that the real energy value of the ration was higher than calculated, thus widening the calorie-protein ratio and accounting for the increased carcass fat. When the MBM was given a value of 2500 the carcass fat was reduced to normal indicating that the calorie-protein ratio had been corrected. This provided conclusive evidence that the actual energy value of MBM was closer to 2500 than to the 1960 value listed in current tables.

Note also that the seven-week body weight and feed conversion of broilers fed 10% MBM were equal to or higher than the corn-soy fed group. These results confirm the results of the report by Jensen (1983) cited above (p. 7).

Table 3. Performance of broilers (males) fed diets formulated with meat and bone meal (MBM) calculated to contain different energy levels (Martosiswoyo and Jensen, 1987)

	Body wt. 7 wks (g)	Feed/Gain (3-7 wks)	Abdominal Fat (% of body wt.)
Males			
Corn-soy	2322^{a}	2.13^{a}	1.54^{c}
10% MBM (1960)[2]	2319^{a}	2.12^{a}	2.11^{a}
10% MBM (2250)	2358^{a}	2.10^{a}	1.91^{ab}
10% MBM (2500)	2377^{a}	2.09^{a}	1.58^{bc}

[1] Values within each column with different superscripts are significantly different ($p < .05$).

[2] The meat and bone meals were all from the same sample but were assigned different ME values in formulating the rations.

POULTRY BY-PRODUCT MEAL

The feeding value of poultry by-product meal (PBM) for poultry was established early in its history which began in the early 1950s. The earliest reports of feeding tests demonstrated that PBM compared favorably with fish meal and all other sources of presumed unidentified growth factors (Romoser, 1955; Fuller, 1956; Naber and Morgan, 1956; Gerry, 1956; Wisman, et al. 1957; Stephenson et al., 1957).

When the composition of PBM is compared with the nutrient requirements of broilers as recommended by the National Research Council (1984) (Table 1) it is apparent that its incorporation into broiler rations provides positive enrichment of energy and all essential nutrients. This makes the marketing of PBM relatively simple. Originally PBM (and poultry fat) were returned by the renderer to the supplier of raw materials to be recycled via his feed to the next generation of poultry. This is still true to a great extent; however, an increasing percentage of PBM is finding its way into pet foods with premium prices being paid for the PBM of the highest quality.

The scarcity of research into the nutritional attributes of PBM since those early reports attests to its acceptability by the poultry (and pet food) industries. Recently Dr. Pesti at the University of Georgia has undertaken extensive research into the nutritional value of PBM. As in the case of MBM it was suspected that the metabolizable energy (ME_n)

value of PBM was underestimated as reported in the various tables of composition in use by the feed industry. Scott et al. (1982) lists ME value of PBM as 2.91 kcal/g and the NRC (1982) as 2.67 kcal/g.

The first report issuing from the Georgia research (Pesti et al., 1986) demonstrated that ME_n values determined by the method of Matterson et al., (1965) were 12% higher when substituted into the test ration at 20% compared with the more conventional 40% substitution. Values were found to be 3.33 kcal/g and 2.97 kcal/g, respectively. Obviously the 20% level of substitution more nearly approached practical levels of use. These findings are similar to those found with MBM when tested at lower levels of substitution (see MBM Section, p. 8).

When Sibbald's true metabolizable energy (TME_n) method was used the TME_n value was found to be 3.55 kcal/g. Projections from relationships found between the ME and the nutrient compositions of their samples to the average sample used by the poultry industry in the southeast indicated an average of 3.39 kcal/g on "as fed" basis.

Jensen and Martosiswoyo (1988) used carcass fat deposition as a basis for estimating energy value just as they had done with MBM (see MBM section, p. 9). From the results of these tests they suggest that PBM should be assigned a value of at least 3.30 kcal/g. This corresponds remarkably closely to the values determined by Pesti et al. (above). Furthermore, they demonstrated that the performance of older broilers fed diets containing poultry by-product meal was better than that expected from the determined ME of the diets. This suggests that older broilers obtain a higher yield of energy from PBM than do younger broilers.

In another report from the laboratory of Dr. Pesti, Escalona and Pesti (1987) observed no difference in performance of broilers when PBM was incorporated into a corn-soy practical ration where all essential nutrients were equalized.

Amino Acid Availability

In the report of Burgos et al. (1974) (see Feather Meal Section, p. 18) the availability of 17 amino acids in PBM ranged from 94%-98% using the chick bioassay of Bragg et al., (1972). Escalona et al. (1986) (U.Ga.) reported that lysine availability determined by the FDNB method of Carpenter (1960) averaged 87% for the three samples of PBM having the highest pepsin digestibility (86%-89%).

FEATHER MEAL (HPF)
(Hydrolyzed Poultry Feathers)

Feathers are almost pure protein. Most of this is keratin protein, which in the raw or natural state is not readily digested by animals. Modern processing methods which cook the feathers under pressure with live steam partially hydrolyze the protein, denaturing it (breaking apart some of the chemical bonds that account for the unique structure of the feather fibers). The resulting feather meal is a free-flowing palatable product that is easily digested by all classes of livestock and poultry.

Feather meal is a <u>concentrated source of protein</u> which can be used to increase nutrient and energy density of poultry feeds, improving feed efficiency, and reducing the amount of feed that must be mixed, handled, and consumed for each pound of poultry meat or dozen eggs produced.

In the early days producers of feather meal encountered a great deal of resistance from poultrymen because of its low or inconsistent digestibility and its low level of certain essential amino acids, particularly methionine and lysine. The extent of these shortcomings is arguable and certainly not sufficient to justify the penalties suffered. A great deal of research had to be carried out and given wide publicity in order to overcome this resistance.

In the meantime the value of feather meal was being demonstrated by reports from Georgia (Fuller, 1956, 1967), Clemson (Naber et al., 1956, 1961), Guelph (Summers, 1969), Iowa State (Morris and Balloun, 1971) and at Maryland (Thomas, 1972).

Since unsupplemented corn-soy rations are equally deficient in methionine and cystine, supplemental methionine must be provided to meet the requirement of young chicks for total sulfur amino acids. Feather meal is very rich in cystine which can provide the needed cystine in practical rations and thus spare expensive methionine which otherwise would be required to supply the cystine in addition to the methionine requirement.

An experiment was conducted several years ago at the University of Georgia (Fuller, 1967) to compare feather meal with fish meal as the sole source of animal protein to supplement a simplified corn-soybean meal ration. The test was conducted under practical conditions with each ration being fed to 1600 mixed sex broilers. In order to determine how much of the total sulfur amino acid (TSAA) needs could be supplied by the cystine in the feather meal, only enough methionine was added in each diet to keep the TSAA content equal. The feather meal ration actually required less added methionine than did the corn-soy ration and it contained considerably less total methionine, but this was compensated or "spared" by the higher level of cystine in the feather meal. As shown in Table 4, there were no significant differences in body weight gain or feed efficiency, demonstrating that at least half of the TSAA requirements can be met with cystine and that feather meal is a good source of this amino acid.

Table 4. The value of feather meal as a source of total sulfur amino acids (Fuller, H.L., 1967)

Calculated analyses	Corn-soy basal	5% Fish meal	3.5% Feather meal
Metabolizable energy (kcal/kg)	3040	3040	3038
Protein, %	24.2	24.3	24.2
Methionine (added), %	0.1	0.04	0.075
Methionine (total), %	0.484	0.479	0.432
Cystine, %	0.373	0.378	0.425
Total sulfur A.A., %	0.857	0.857	0.857
<u>Results</u> (2-8 wks)			
Body weight gains (lbs)	3.66	3.72	3.71
Feed/gain	2.25	2.20	2.24

Morris and Balloun (1971) at Iowa State University studied the influence of processing conditions on the nutritional value of feather meal in broiler diets. The different feather meals were used to supply 5% or 7.5% protein, replacing soy protein in a corn-soy basal ration varying in total protein from 16%-22%. Diets at each protein level were made isocaloric and isonitrogenous. Lysine and methionine were added to bring all diets up to NRC standards (calculated on tabular values) for these amino acids. All five feather meals produced excellent results when used to supply 5% protein at all protein levels clearly indicating that the protein and amino acids in the feather meals were equally as available to the chick as were those in the soybean meal.

When the feather meals were used to supply 7.5% of protein, gains and feed efficiency were generally lower. This was especially true for the low protein diets in which almost all of the soy protein was replaced with feather meal protein. At this point deficiencies of the next limiting amino acids would be encountered and performance would be a reflection of total amino acid levels rather than availability.

In a research report from the University of Guelph Summers (1969) demonstrated the extent to which feather meal can be used in practical broiler rations (Table 5). The corn-soy and corn-soy-feather meal rations were calculated to be equal in protein and energy. Feather meal protein replaced an equal quantity of soy protein up to the point where the first essential amino acid became limiting in the diet. Hence the starting diet contained 6% feather meal and the finishing diet contained 4.1% feather meal. No difference was observed in growth or feed efficiency of chicks fed the two diets, demonstrating that feather meal is a good source of protein if used properly in a diet.

Table 5. Growth and feed utilization of male broilers (Summers, 1969)

Treatment	9-week av. wt.	Feed/gain
	(lb.)	
corn-soy	4.58	2.27
corn-soy-feather meal	4.59	2.27

In similar experiments conducted at the University of Maryland (Thomas et al., 1972), feather meal was fed to 12-day-old chicks at levels ranging from 0-7% for a 2-week period. Two diets were formulated, the control and a 7% feather meal diet. These were blended to give 8 diets from 0-7% feather meal. There were no significant differences in growth rate or feed conversion, demonstrating that feather meal can be added up to 7% of the diet without adversely affecting performance of broiler chicks.

At the University of Arkansas a report from Stephenson's laboratory (Burgos et al., 1974) has provided amino acid content and availability data on feather meal, poultry by-product meal, a combined feather and poultry meal cooked together and a blend of the two cooked separately. Average availability of all amino acids exceeded 95% with individual values ranging from 92%-98% in those products cooked separately. Greater variation occurred both within and between samples when the feathers and offal were processed together. This report proved to be a real breakthrough which led to increased usage of feather meal and poultry by-product meal in broiler rations.

More recently Baker et al. (1981) carried out chick bioassays with feather meal and demonstrated that at least 10% of the dietary protein could be supplied with feather meal supplemented with methionine. With both lysine and methionine supplementation up to 40% of the crude protein could be supplied by feather meal without affecting growth or feed efficiency.

Metabolizable Energy Value of Feather Meal

One of the most critical nutritional characteristics of any feed ingredient in sophisticated feed formulation is its metabolizable energy (ME) value. Early reports of ME values of feather meal were apparently based on samples having very low digestibility. For example, Sibbald et al. (1962) reported a value of 1.0 kcal/g and concluded that feather meal was a poorly digested protein. Summers (Univ. of Guelph) challenged this value and reasoned that if the protein in feather meal was 90% available, the meal should have an ME content of 3.08 kcal/g. Summers et al. (1968) assigned an ME value of 3.01 kcal/g for feather meal. Most of the analysis tables in wide use today list the ME content of feather meal at or near 2.3 kcal/g (Scott, 1984; NRC, 1984; Feedstuffs, 1987).

Recent studies at the University of Georgia (Fuller and Dale, 1986) found an average true metabolizable energy (TME) value of 3.07 kcal/g for four samples of feather meals being marketed in the Southeast. Later research from the University of Georgia (Pesti et al., in press) lists the average of TME_n and AME_n assays of feather meal as 3.36 kcal/g DM using cockerels. This is close to the mean value of 3.42 kcal/g DM found in Sibbald's 1986 table. (These values are equivalent to 3.12 and 3.18 on an "as is" basis.)

Reduction of Abdominal Fat Content of Broilers with Feather Meal

Cabel, Goodwin and Waldroup (1986) at the University of Arkansas reported that feather meal at levels of 4%-6% in broiler rations for 7-14 days prior to slaughter resulted in significant reduction of abdominal fat content without adversely affecting growth or feed utilization.

Development and Evaluation of Procedures for Determination of Protein Digestibility and Amino Acid Availability

Several years and over $100,000 have been invested by FPRF in the effort to develop an *in vitro* procedure that would predict actual protein digestibility in the animal more accurately than does the current official AOAC pepsin digestibility method. Hopefully the method also could be accomplished more rapidly.

The work of Dr. Coon, began at Washington State Univ. and continued in recent years at the University of Minnesota, has developed a method involving pepsin and pancreatin that requires only 4 hrs digestion time with less than one full day turn-around time. We have had some problem with Dr. Coon trying to infuse into this work the larger question of overall protein quality. Such a concept confuses the two basic problems of digestibility and amino acid content. All of this has been good basic research and the findings will no doubt be of value to the poultry and livestock industries. He has agreed to extract that portion of his work dealing specifically with protein digestibility and presenting it in a format that can be submitted to the AOAC to be considered for adoption as the official method.

The research of Dr. Parsons at Illinois has been completed. He has compared *in vitro* (pepsin) digestibility with biological assays. His work corroborates that of Coon (and several others) to the effect that pepsin digestibility values for feather meal and meat + bone meal (HPF and MBM) were much lower when determined with 0.002% pepsin than with 0.2% (the current official method) and the 0.002% pepsin values were more highly correlated with bioassays.

Dr. Parsons conducted 5 amino acid digestibility trials on 9 HPF, 14 MBM, 9 PBPM and 8 BM using both conventioned (CONV) and cecectomized (CEC) cockerels. True digestibility of 15 amino acids in HPF averaged 81% for CONV cockerels and 76% for CEC cockerels. True metabolizable energy of HPF was 3.647 kcal/g for CONV birds and 3.352 for CEC birds. (These values are very close to those found by Pesti (1986) and represent virtually complete utilization of the protein and fat in the HPF.)

Four chick growth assays revealed bioavailability values in HPF ranging from 30% to 79% for lysine and 64% to 79% for methionine plus cystine. For MBM lysine bioavailability values ranged from 51% to 94%.

BLOOD MEAL

Blood meal is the richest source of both protein and lysine available to the feed industry yet poultrymen in particular have been reluctant to accept it as a feed ingredient. Early research reports pointed out the poor growth response of both laboratory animals and poultry when fed high levels of blood meal. This early reputation was probably caused by one or both of two factors: (a) blood meal is quite deficient in the amino acid isoleucine, as are most grains. Thus, if blood meal were used to supply a substantial part of the protein, the diets would be first limiting in isoleucine; (b) most of the blood meal was prepared by the vat-dried method which was shown by Kratzer and Green (1957) to contain lower levels of available lysine compared with spray-dried blood meal.

During the next three decades improvements were being made in processing of blood meal to enhance the availability of its amino acids. Attention was focused on lysine because the greatest demand on blood meal was for that amino acid. The high level of lysine in blood meal made it a prime candidate to supplement the inherently lysine-deficient grain-based rations. Furthermore, lysine is easily destroyed with increasing time, temperature, and pressure.

In laboratory studies Hamm and Searcy (1976) demonstrated the effect of processing conditions on available lysine in blood meal. The available lysine, determined chemically, was decreased as temperature and time of exposure increased.

Several blood meals were assayed for lysine availability by Noll et al. (1984) at the University of Minnesota using the turkey bioassay, acid hydrolysis chromatographic assay, and the FDNB chemical method. Vat-dried blood meal contained significantly less total FDNB available, and bioavailable lysine compared to spray, DeLaval-Anderson, or ring-dried blood meal. Bioavailability estimates where gain was regressed on feed lysine content produced less variable results.

The same workers (Waibel et al., 1987) have conducted a series of experiments testing feather meal, meat and bone meal and blood meal fed separately or in various combinations in practical turkey rations. Some of the data reported are shown in Table 6. When diets were equalized in nutrient composition according to the NRC Requirements (1984), there were no differences in body weight gains among treatments. All treatments resulted in body weights greater than the standard published in Turkey World (Sell, 1986). The combination of MBM, feather meal, and blood meal resulted in significantly greater feed efficiency than that of the controls.

Table 6. Body weight and feed conversion of male turkeys at 20 weeks of age (Waibel et al., University of Minnesota, 1986)

Treatment	Body wt. (kg)	Feed/wt. (kg/kg)
1. Corn-soy control[1]	13.76^{ab}	2.909^{abc}
2. Feather meal, 2%	13.62^{abc}	2.876^{abcde}
3. Feather meal, 4%	13.48^{ab}	2.939^{a}
4. Meat and bone meal, 7%	13.71^{ab}	2.829^{cde}
5. as 4 + 4% feather meal	13.72^{a}	2.840^{bcde}
6. As 4 + 4% blood meal	13.31^{abc}	2.814^{de}
7. As 5 and 6 combined	13.56^{abc}	2.797^{e}
8. As 1 with lower protein[2]	13.23^{bc}	2.890^{abcd}
9. As 8 with 4% feather meal	13.09^{c}	2.917^{ab}
10. As 9 using avail. A.A.	13.43^{abc}	2.862^{abcde}
Sell's growth standard (<u>Turkey World</u>, 1986)	12.44	

[1] Diets 1-7 formulated according to NRC 91984) nutrient requirements/therm metabolizable energy.

[2] Diets 8-10 formulated to 90% of NRC (1984) recommendations for methionine and lysine.

General suggestions by the author were to utilize blood meal at 2%, feather meal at 2%-4% and meat and bone meal 7%-8% of the ration.

APPENDIX 1

Nutrient Composition of Protein Supplements[1,2]

	MBM	PBPM	BlM[3]	HPF	SBM	FM
Metab. energy (poultry) kcal/kg	2444[4]	3300[4]	3240	3075[5]	2530	2820
Protein, %	50.4	50.0	88.9	86.4	38.5	60.5
Fat, %	8.6	13.0	1.0	3.3	1.0	9.4
Calcium, %	10.1	3.0	0.3	0.33	0.27	5.0
Phosphorus (avail.), %	5.0	1.7	0.25	0.55	0.2	2.8
Ash, %	28.6	16.0	4.8	4.0	6.0	19.1
Sodium, %	0.72	0.40	0.33	0.71	0.03	0.41
Chlorine, %	0.74	0.54	0.27	0.28	0.05	0.60
Selenium, mg/kg	0.25	0.75	----	0.84	0.10	2.10
Zinc, mg/kg	3.0	120	306	54	45	147
Choline, mg/kg	1996	5952	280	891	2731	3056
Niacin, mg/kg	46	40	13	27	22	55
Pantothenic acid, mg/kg	4.1	12	5	10	15	9
Riboflavin, mg/kg	0.4	4.4	1.3	2.1	2.9	4.9
Vit. B_{12}, mg/kg	0.07	0.3	0.04	0.07	---	0.10
Arginine, %	3.62	4.11	3.80	5.40	3.68	3.79
Glycine, %	6.79	5.90	4.00	6.30	2.29	4.19
Histidine, %	0.90	1.50	5.26	0.34	1.32	1.46
Isoleucine, %	1.40	2.00	0.88	3.26	2.57	2.85
Leucine, %	2.80	3.70	11.80	6.72	3.82	4.50
Lysine, %	2.60	2.70	8.85	1.67	3.18	4.83
Methionine, %	0.65	1.00	0.75	0.42	0.72	1.78
Meth. + Cyst., %	1.14	1.69	1.61	4.42	1.45	2.34
Phenylalanine, %	1.50	2.00	6.55	3.26	2.11	2.48
Phen. + Tyr., %	2.26	2.54	9.04	9.57	4.12	4.46
Threonine, %	1.50	2.00	3.94	3.43	1.91	2.50
Tryptophan, %	0.28	0.53	1.34	0.50	0.67	0.68
Valine, %	2.0	2.60	8.60	5.57	2.72	3.23

[1] Values from NRC (1984) except as noted

[2] "As fed" basis

[3] Spray or ring dried

[4] Estimated from report of Jensen (1987)

[5] Fuller and Dale (1986)

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