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FATS AND PROTEINS RESEARCH FOUNDATION, INC.

DR. GARY G. PEARL D.V.M.
Director Technical Services
16551 Old Colonial Road
Bloomington, Illinois 61704
Telephone: 309-829-7744 FAX: 309-829-5147
<www.fprf.org>

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Use of Ruminant Meat meals and other Rendering By-products by the Poultry Industry

Dr. Jeffre D Firman* and David Robbins
***Professor of Nutrition**
116 ASRC University of Missouri
Columbia, MO 65211 USA
firmanj@missouri.edu
573-882-9427
573-882-6640 Fax
and
Dr. Gary G. Pearl
Fats and Proteins Research Foundation, Inc.

Introduction

There has been a long history worldwide of use of animal proteins in the poultry industry. Essentially all sources of proteins have been and continue to be used in significant quantities in the US with the primary issue being relative values compared to other protein sources such as soybean meal. Products currently being utilized include meat meals from ruminant origin, swine origin and poultry origin as well as the blood products from each of these, fat products from each of these and feather meal. Additionally there is now some limited production of whole hen meal used as a disposal method for spent laying hens. Each of these products has been used successfully at various levels in the rations of poultry of all types with the higher levels going into broilers and turkeys due to their higher relative protein needs in comparison with layers.

These products of animal origin provide nutrients needed by poultry at reasonable prices relative to competing products and in fact prices tend to fluctuate based on prices of competing products. There has also been some interest in replacement of a portion of the soybean meal in poultry rations with animal products to improve performance. The oligosaccharide portion of soybean meal has been shown to produce some detrimental effects to poultry. This is thought to be due to a substance in the undigested portion of the product that irritates the footpad. The addition of animal protein sources may improve performance parameters significantly over standard diets. While these results may be due to high levels of limiting amino acids, it may also be explained by the reduction of poorly digested carbohydrates in the soybean meal. Previous work in Dr. Firman's laboratory has suggested that up to half of the protein source can be provided with mixed by-products if one formulates correctly. While each product has different nutrient contents and potential values, most are excellent sources of high quality protein, highly available phosphorus and other minerals. Animal proteins are an excellent source of numerous essential minerals that plant proteins do not supply. They additionally do not contain antinutritional components common to plant proteins.

With the recent case of BSE in the US, there has been a substantial alternation in market structure correspondingly price of ruminant derived product. While the safety of the product will be discussed later in this document, let's first address the use of ruminant derived meat and bone meal in poultry diets as well as the use of other by-product feeds. The goal is to provide the information needed to utilize these products in ration formulation, methodology for their use and limitations on their use as well as show something on the economics of their use. Ultimately with this information in hand, proper decisions about the use of these products can be made and money saved.

Available products

Ruminant meat meals: These are products that are produced from the rendering industry that consist of the non-edible portion of cattle processing. These products may vary somewhat, primarily based on the relative proportion of bone in the product. These are products that are heavily utilized in the US poultry industry from the standpoint as a protein source, but also as calcium phosphorus and energy sources. Inclusion levels are primarily limited by the potential for excess phosphorus and of course the computer formulation will only allow for inclusion when justified by price, but 10% of the ration is commonly fed. This discussion of the use of animal origin products will focus on the ruminant meal due to the current low prices, but most information will be applicable to other products as well.

Poultry By-product meal: This product is the by- product of the poultry processing industry and may consist of the offal and other inedible parts of the chicken. The main cause for differentiation of the products is based on the processing source. This may include portions of the chicken such as the deboned carcass in a further processing plant while one which sells primarily whole birds may not have this portion of the bird and thus will have different levels of ash content. This product has become more expensive in some cases as the high quality has led to use by the pet food industry in the US. The fat content of the product consists of course of the fat from birds which is less saturated and thus may contribute to less saturation in the meat birds fed the product. Again inclusion of the product is primarily limited by ash content, but is most commonly around 10% again.

Blood meal: This is a product based on a drying process from the blood processed in chicken or beef plants. The more sophisticated the drying process, in general the better the product produced. Thus spray drying is generally considered superior to vat drying. A significant portion of blood meal is used for production of plasma proteins, although porcine blood is probably most heavily used for this. Blood meal is generally not used in high concentration in poultry diets due to its amino acid balance. Constraints would be at 1-2% of the total ration.

Feather meal: Feather meal is the ground and hydrolyzed feather from chicken and turkey processing. Generally feather meal is considered to be low in digestibility and with a poor amino acid balance and is thus not heavily used in the poultry industry. It is generally economically priced, and will normally be used at a maximum of 1-3% of the ration. Higher levels can be fed when careful formulations are used, but this is rarely cost effective.

Blends: Several commercial blends are available as well as the ability to have products custom blended to customer specifications. Generally this will increase costs somewhat and may not be a cost effective alternative. Blends were more heavily utilized in the past. Some products were designed specifically as a replacement for fish meal for instance. The value of blends has gone down as computer formulation has become more widely available and as formulation of diets on a digestible amino acid basis has become more widely accepted. The use of computers has allowed for basically a custom blend to be made for each diet based on the available ingredients and their cost effective use.

Animal Fats and animal vegetable blends: A number of different types of fats can be used by the poultry industry depending on cost and availability, but will include tallow, choice white grease, poultry fat, yellow grease and blends of the above. Fat inclusion is generally a price issue based on calorie cost. In general, fat can be fed at high levels with performance enhancement, but is limited by cost and the physical ability of the feedmill to mix fat into the diets.

Review of literature

There has been considerable work done with meat and bone meal, particularly in the area of protein and amino acids. Firman (1992) found that the amino acid digestibility of meat meal does not differ in turkeys of different age or sex and is similar to the rooster model commonly used. Lysine and methionine are highly available for metabolism, but a significant amount of the cystine is not bioavailable (Wang and Parsons, 1998a). This is of importance because tryptophan and TSAA are most limiting in meat and bone meal for poultry, followed by threonine, isoleucine and phenylalanine + tyrosine, methionine, lysine, and valine and histidine (Wang et al., 1997). Several reports have found that the protein quality of meat and bone meal varies greatly. Parsons and co-workers (1997) found that the ash content is correlated to the protein quality. It is thought to be a caused by the ratio of protein to ash in a ration. As ash increases, protein decreases. The amino acid digestibility is probably not actually but diluted (Shirley and Parsons, 2001). The method of determining digestibility can also have an effect, often yielding differing results (Johns et al., 1987). Fat additions to rations have also proved to be a factor as increased digestibility has been shown in the presence of high levels of fat. Increasing the fat component of a diet can slow gut motility, leaving more time for absorption. The micelles themselves may also help transport amino acids to the gut wall (Firman and Remus, 1994). Digestibility can also be affected by the presence of other ingredients, like soybean meal (Angkanaporn et al., 1996). It has been shown that formulating rations based on digestible or bioavailable amino acid levels provides better results than on a total amino acid basis (Wang and Parsons, 1998b).

One of the most important factors determining the nutritional quality of meat and bone meal is the processing procedure. With recent concerns over bovine spongiform encephalopathy (BSE), feeding ruminant-derived meat and bone meal to ruminants is banned in the United States and the European Union (EU) has banned the feeding of all products of animal origin to livestock. This leaves the poultry, swine, aquaculture and companion industries as the major consumers of meat and bone meal. When a meal is rendered, the time, pressure, and temperature of rendering may vary. The EU has mandated that animal by-product meals must be processed at 133°C and 30 psi for 20 minutes to increase safety. Unfortunately this rendering process does not always inactivate the prion thought to be responsible for BSE. Therefore, studies have been done to determine the nutritional effects of differing pressure, time, and temperature effects. While increasing pressure may reduce the possibility of BSE infection, it also decreases the availability of nutrients for the bird (Shirley and Parsons, 2000). Temperature also has proven to affect the availability of nutrients. Temperature has the same inverse relationship to nutrient availability as seen with pressure (Johnson et al., 1998), as does the processing time (Karakas et al., 2001). Constant improvement in processing technology has recently resulted in improved nutrient availability as is demonstrated by Table #1A. However, variation in quality is still an issue for the industry (Elkin, 2002).

Table 1A. Digestibility Coefficients of Selected Amino Acids in Meat and Bone Meal as Reported in Literature since 1984.

Amino Acid	1984 [(1)]	1989 [(2)]	1990 [(3)]	1995 [(4)]	1997[(5)]	2000 [(6)]
Lysine, %	65	70	78	92	71	87.5 – 92
Threonine, %	62	64	72	89	-	80.2 – 88.9
Tryptophan, %	-	54	65	-	70	86.4
Methionine, %	82	-	86	91	-	87.4 – 92
Cystine, %	-	-	-	71	-	76.4

[(1)]Jorgensen et. al. 1984. Determined at the ileum of pigs. [(2)]Knabe et. al. 1989. Determined at the ileum of pigs. [(3)]Batterham et. al. 1990. Determined at the ileum of pigs. [(4)]Parsons. 1995. High quality meat and bone meal in poultry using the precision fed cockerel balance assay. [(5)]Bellaver, Easter, Parsons 1997 determined at the ileum of pigs. [(6)]FPRF Reports. 2000. Upper range values for MBM as determined via Ileal, intestinal & cockeral assays. (Cromwell, Parsons, Klopfenstein projects)

Several other studies have looked at the ideal amount of meat and bone meal to be added to a ration. The level of inclusion of meat and bone meal to usual rations has been debated because of variations in metabolizable energy, protein quality, and available phosphorus. It is often included at five percent or less of the ration. However, Sell (1996) found that meat and bone meal can be added successfully to diets at up to 10% for turkeys.

As given in the name, bone is a component of meat and bone meal. This provides an excellent source of calcium and phosphorus. Drewyor and Waldroup (2000) noted that inclusion of meat and bone meal must be monitored to insure phosphorus levels are not so high that environmental issues arise. Others have found that the phosphorus in meat and bone meal is highly available to poults (Sell and Jeffrey, 1996). Fortunately, prediction equations for phosphorus content have been developed similar to those used to predict the metabolizable energy of a feedstuff. This rapid determination will aid in the formulation of rations utilizing meat and bone meal (Mendez and Dale, 1998).

Of primary concern is the metabolizable energy of meat and bone meal. As mentioned previously, the variability of the feedstuff makes it difficult to precisely determine a standard value. Waring (1969) found an ME of 1,988 kcal/kg, lower than many estimates. The National Research Council (1994) uses a value of 2,150 kcal/kg. However, early papers tended to underestimate the ME of meat and bone meal, with it probably being between 2,300 and 2,500 kcal/kg (Martosiswoyo and Jensen, 1988a; 1988b; Dolz and de Blas, 1992). Species tissue origin may also have an effect. Dale (1997) found a ME of 2,449 kcal/kg for beef meat and bone meal and 2,847 kcal/kg for pork meat and bone meal, while others found no differences in species (Karakas et al., 2001).

Use of Animal Proteins in Rations

Animal proteins are a useful constituent of poultry rations. They provide a high level of protein/amino acids, highly available phosphorus, a number of other minerals and moderate amounts of energy. While historically there have been some limits on the use of animal products in poultry rations, most of these have been artificially set due to a lack of information. Much of that information is now available and use of products is more closely tied to the economics of the products relative to competing products. Before looking at some ideas and methodologies for using these protein products, let's look at what has happened in the research world in a general sense relative to their use as this has been a tremendous source of confusion that deserves some explanation. When fed in a variety of these trials, one sees everything from a nice positive response to no response to a very negative response. While each of these responses can be found, an understanding of why the differential response occurs is needed.

Animal protein meals provide a negative response: Animal protein meals have been used successfully in the US and around the world for a number of years with excellent results. Why then are there data out there that show a negative response to their dietary incorporation? There are several reasons for this. In some cases the research was just poorly designed. An example of this might be the use of an energy value that is higher than the actual value of the product. This would result in an actual decrease in dietary energy as we added more of the product to the diet. Probably the main reason for poor results from trials using animal protein meals is that diets were not formulated using digestible amino acids. When this occurs, if we are formulating very close to the actual requirement, we can inadvertently create a deficiency of an amino acid. This can occur if we replace a highly digestible ingredient with one that is lower in digestibility. The example diet below is a starter turkey ration that compares a corn-soybean meal diet with one in which a meat product has been added to the ration. Note the 5% reduction in available lysine and the 15% reduction in methionine. As long as we overfeed nutrients, which is a common practice, this will not be an issue since the requirements of the animal are still being met. However as we move towards more precise feeding methodology (precision feeding) this is certainly an issue. Obviously, if one is computer formulating on a digestible basis, no depression in growth will occur. Another cause of a negative response would be a nutrient imbalance (usually seen only at high inclusion levels without constraints to control such) whereby several nutrients become out of balance due to the levels found in the meat and bone meal itself. An example of this might be the Ca:P ratio. Meat meal may provide a significant portion of these nutrients, but not necessarily in the correct ratio for the diet. If this is not taken into account in the formulation matrix, negative results may occur.

Table 1. Comparison of two formulations based on total amino acid content and the effect on digestible amino acid values

	Corn-soybean diet		By-product addition diet	
	Total Basis	Digestible Basis	Total Basis	Digestible Basis
Lysine	1.72%	1.52%	1.72%	1.45%
Methionine	0.55%	0.52%	0.55%	0.44%
Threonine	1.05%	0.86%	1.05%	0.84%

Animal proteins provide similar response: This is the most common research outcome and should be expected. A knowledgeable nutritionist should be able to get similar responses with a number of different ingredients. Use of animal protein products up to inclusion levels that would typically be cost effective such as 12% in a broiler starter diet should result in similar performance when compared with diets that contain no animal products when formulation is based on the types of parameters mentioned above.

Animal proteins provide a positive response: In some cases, the addition of animal proteins to a diet will provide a positive response (i.e. improved growth rate). Assuming that diets, etc. were formulated correctly, the most likely cause of this is balancing of the amino acid profile relative to the needs of the animal. This is something that occurred with fish meal addition (resulting in a perceived need for fish meal) and in fact this effect was sought by some of the companies that blended meals together.

Safety of Animal By-Product Ingredients

Rendering is a process of controlled heating to remove moisture, facilitate fat separation, and produce aseptic material. Depending on the exact process, temperatures of 240 degrees to 285 degrees Fahrenheit (F) at corresponding times provide for the inactivation of bacteria, viruses, protozoa, and parasitic organisms. Animal protein meals have been stigmatized and more closely scrutinized for bacterial contamination, especially for *Salmonella*, than other feed ingredients. *Salmonella* are destroyed by heat when exposed to temperatures of 130 degrees F for one hour or at 140 degrees F for 15 minutes. Thus the opportunistic and ubiquitous nature of *Salmonella* and other pathogenic bacterial may re-contaminate products after cooking or processing, during storage, transport, and handling. Post process contamination is of concern for all feed ingredients and not restricted only to animal proteins. Davies and Funk (1999) completed an extensive review of *Salmonella* epidemiology and control. This report, as well as other databases, suggests that all feed ingredients may be contaminated with *Salmonella* (see Table 2).

Table 2. Incidence of Salmonella In Feed Ingredients.

Ingredient	Item	Country				
		Netherlands [a]	Germany [b]	USA [c]	Canada [d]	United Kingdom [e]
Animal Proteins	Samples	2026	17	101	Not reported	120
	% Positive	6	6	56	20	3
Vegetable Proteins	Samples	1298	196	50	Not reported	2002
	% Positive	3	26	36	18	7
Grains	Samples		37		Not reported	1026
	% Positive		3		5	1
Fish Meal	Samples				Not reported	1316
	% Positive				22	22

[a] *Beumer and Van der Poel, 1997*
[b] *Sreenivas, 1998.*
[c] *McChesney et al., 1995*
[d] *Canadian Food Inspection Agency, 1999*
[e] *Brooks, 1989*

It is now recognized that feeds of plant origin, i.e., soybean meal and corn, are often contaminated with *Salmonella.* The rendering process has been shown to be one of the most efficacious methods for processing the raw inedible by-product materials from animal production. Incineration and alkaline/acidic digestion, though microbiologically effective, result in nutritional denaturation of the material. Rendering, which utilizes a time/temperature control process, preserves the nutrient contents of the derived ingredients.

Table 3. Efficacy of the United States Rendering System in the Destruction of Pathogenic Bacteria [a]

Pathogen	Raw Tissue [b]	Post Process [b]
Clostridium perfringens	71.4 %	0 %
Listeria species	76.2 %	0 %
L. monocytogenes	8.3 %	0 %
Campylobacter species	29.8 %	0 %
C. jejuni	20.0 %	0 %
Salmonella species	84.5 %	0 %

[a] *Trout et al., 2001. Samples from 17 different rendering facilities taken during the winter and summer.*
[b] *Percent of the number of samples found to be positive for pathogen out of the total samples collected.*

Table 3 provides data that illustrates the high incidence and content of foodborne microorganisms within raw animal by-product material (Trout et al., 2001). Further, the table provides data to demonstrate the efficacy of the rendering process in killing *Salmonella* and other pathogenic bacterial organisms that may be present in raw animal by-products.

In addition to the market interruption created by the North American diagnosis of BSE, the biosecurity and safety of animal by-products have been under enhanced scrutiny. There has been no evidence of transmission of any of the transmissible spongiform encephalopathy (TSE's) to poultry. This would include BSE.

Oral challenges – BSE to Chickens

The Veterinary Laboratories Agency, Webridge, UK under the direction of Dr. Danny Mathews (Mathews 2001) conducted oral challenge studies using infective BSE infected brain stem into chickens. The oral challenge consisted of 5 grams of infected tissue given by oesphageal tube into the crop of broiler chickens at 4, 5 and 6 weeks of age. For perspective, it is believed that 10 milligrams of infective brain tissue can initiate bovine infection. The challenged chickens were taken to a 57 month endpoint with no symptoms or infectivity in the birds tissues at endpoint.

Parental Challenges – BSE to Chickens

Studies were also conducted by Dr. Mathews incorporating intracranial and intraperitonal inoculations of infected bovine brain stem material into young male chickens. The parental challenge consisted of 50 micro ml intracranial and 1 ml intraperitoneal. Chickens were again taken to a 57-month endpoint. Chickens that showed any "motor disturbance" following inoculation were sacrificed and tissues sub-passaged back to chickens observing for any subclinical form of disease. Sub-passage in mice was also attempted. These studies are complete with confirmed negative findings.

The oral, intracranial and intraperitoneal inoculations provided extreme challenge not perceived to represent natural exposure. The research was conducted using raw nervous system tissue when in actuality food or feed ingredients are heat processed. Research has shown that heat does not destroy the infective agent but does lower its infectivity by a number of log reduction factors.

Species to Species Feeding

An intensive literature search was conducted by Denton et. al. (Denton 2003) to assess the scientific evidence that same species feeding or properly processed animal by-products posed any animal or human health risks. Aside from the currently accepted ruminant to ruminant prohibition as a preventive for BSE in cattle there were no risks documented in the literature base to validate that species to species feeding practices should be causation of concern.

Many farm animals, domestic pets including fish show cannibalistic tendencies both under "natural" as well as modern production practices. Such practices in poultry are feather and tissue picking and preying on dead or weakened group mates. Many of these tendencies have been prevented or alleviated by including animal by-product ingredients in the diet. Animal by-product ingredients having been properly processed have no physical resemblance to the pre-processed by-product. The rendering process completely decharacterizes muscle, fat and other animal tissues into a protein rich granular-type textured meal and fats with specific nutritional components that has absolutely no resemblance to the raw material. The term cannibalism is not appropriate descriptions for animal by-product ingredients.

Currently several countries including the USE, are experiencing Avian Influenza, (flu) disease breaks. Though little research has been conducted with the respective strains of the influenza virus, validation that the rendering process inactivates viral diseases have been completed. Studies completed by Dr. Eugene Pirtle at Iowa State University, confirmed that the pseudorabies virus (PRV) was inactivated in properly processed meat and bone meal from naturally-infected swine as well as tissue experimentally inoculated with PRV prior to processing via rendering.(Pirtle 1990) Viral isolation and disease transmission was not accomplished in the rendered meat and bone meal. PRV belongs to the alphavirus subfamily of Herpesviridae. A family that includes viruses with broad host ranges with the ability to establish latent infections in specific host tissue. Thus the PRV has served as an appropriate model for other virus types.

Use and economics of animal protein meals

In more recent years, the focus of nutrition has shifted away from providing maximum growth to providing the maximum cost efficiency, since growth has become relatively easy to obtain. Basically maximum growth is obtained when all nutrients are provided in excess. While it is possible to provide too much of a nutrient and inhibit growth, cost issues dictate that this is rarely a real world problem. In the new search for cost efficient production, terms like Ideal Protein, Precision Feeding and Best Cost Nutrition are what is important as these will ultimately lead to the least cost / unit of gain. Animal protein meals fit into this cost efficiency program as a well priced protein source with some other nutrients of value as well. We'll take a stepwise approach at this to see how a product such a ruminant meat and bone meal can be used.

1. The first step towards use of the products available is to gather the information on pricing of your current ingredients and their nutrient specifications. This should be done based on a known criteria such as delivered to the mill in the form used by your mill. In other words, if you need bagged feed on pallets delivered, then this is how the price calculations must be done so the comparisons are accurate.

2. Next gather information on the products that you have the potential to use. We'll just use ruminant meat and bone meal as an example. You will want the complete nutrient profile of the product including digestible amino acid levels if you formulate on this basis. You will also need good pricing information, again based on delivery criteria as mentioned previously.

3. With the information gathered, we can then input data into the computer and take a look at what happens to our price structure. Below we have gone through this exercise with prices for soybean meal set at US$240/ ton and then set our meat and bone meal at a percentage relative to this price since prices fluctuate based on market conditions. We have gone very low on prices due to the current price structures. Nutrient specifications were set at the US National Research Council levels for a broiler grower. With a straight corn-soybean meal diet we come in at a base price of $141.12 (Table 4). As we add meat and bone meal to the diet we see cost savings with the greatest savings at the highest level of addition and obviously with a lower price than soybean meal. Generally meat and bone can be had for the same or lower price than soybean meal and thus cost savings from this move alone can be substantial as can be seen in the diet with meat and bone at 110% of soybean meal still resulting in savings. Currently, prices are depressed and this can be seen in the final diet where we used a price of 40% of soybean meal and saved almost $20/ton. Needless to say this is a substantial savings over a corn–soybean meal diet. Please note that in diets where the meat meal price was less than 84% of the soybean meal price, a maximum constraint must be used or the computer will delete meat and bone meal in with total replacement of soybean meal. This constraint could be on calcium, available phosphorus or meat meal itself.

Table 4. Comparison of diets with differing levels and prices of meat and bone meal expressed as a percentage of soybean meal price (prices per ton in US dollars)

		Price of Meat meal relative to soybean meal					
	Base	110%	100%	90%	84%	<84%	40% *
Meat meal %	----	6.05	7.70	7.70	7.70	++++	10
Calcium %	.90	.90	.90	.90	.90	++++	1.13
Phosphorus %	.35	.35	.41	.41	.41	++++	.50
Price/ton	141.12	136.40	134.81	132.81	132.07	131.85	121.32

*Constrained at 10% Meat and bone meal addition

4. The next step along this path is to look into use of multiple products at the same time. In general as one provides more choices (poultry by-product meal, feather meal as examples) for the computer to choose from, we see a more accurate nutrient balance (less excess nutrients fed) as well as cost savings. More information (Firman, 2003) on strategies for saving costs through use of computer formulation is available.

Determination of energy content of meat meals

One of the concerns expressed when using meat and bone meals is the determination of energy content of the diet. Recent work by Dr. Firman examined a variety of methodologies that have been used over the years to determine the energy content of feedstuffs. While some differences occur by method, in most cases all of the methods provided similar numbers. An equation that predicts energy values is included in Table 9.

Table 5. Proximate and Mineral Composition of Meat and Bone Meal Products

Sample	Gross Energy	CP	Moisture	Fat	Ash	Ca	P	K	Na	Fe
	Kcal/kg	%	%	%	%	%	%	%	%	Ppm
mbm-2	3,880	53.8	6.2	10.8	27.3	8.3	4.0	0.42	0.83	1,265
mbm-3	4,130	50.4	8.2	10.3	28.9	9.3	4.7	0.46	1.05	381
mbm-5	4,200	50.9	6.5	9.7	31.1	10.3	4.5	0.44	0.85	365
mbm-7	4,439	59.0	7.9	8.4	23.9	8.1	4.3	0.54	0.68	258
mbm-8	4,147	58.5	4.4	12.3	23.3	8.3	4.2	0.63	0.71	437
mbm-9	4,347	51.9	5.8	12.4	27.0	9.0	4.5	0.59	1.14	456
mbm-10	4,384	51.1	3.5	11.5	26.8	*	*	*	*	*
mbm-12	3,516	48.3	6.3	8.2	27.3	11.8	5.9	0.40	0.92	564
mbm-13	3,728	52.4	7.8	12.1	23.6	7.5	3.8	0.64	1.04	724
mbm-14	3,779	50.1	5.0	8.6	34.2	12.1	6.0	0.47	1.11	228
mbm-15	4,349	58.9	5.2	9.4	25.7	8.9	4.6	0.63	0.88	401
mbm-16	3,077	45.7	7.0	9.0	37.7	13.6	6.8	0.33	1.10	226

*Data unavailable.

Table 6. Mean Metabolizable Energy Values for each Assay Method of each Meat and Bone Meal Product (kcal/kg)

Sample	**mbm-2**		**mbm-3**		**mbm-5**	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TME_n	2,240 ^{bc}	90	2,469 ^{a}	74	3,026 ^{a}	61
Turkey TME_n	2,528 ^{ab}	81	2,517 ^{a}	74	2,600 ^{bc}	79
Chick Digesta AME_n	2,135 ^{c}	81	2,436 ^{a}	74	2,555 ^{c}	61
Chick Excreta AME_n	2,508 ^{ab}	81	2,577 ^{a}	74	2,751 ^{abc}	61
Chick Excreta $aAME_n$	2,475 ^{abc}	81	2,614 ^{a}	74	2,786 ^{abc}	61
Poult Digesta AME_n	2,722 ^{a}	90	2,454 ^{a}	74	2,882 ^{ab}	69
Poult Excreta AME_n	2,586 ^{ab}	90	2,510 ^{a}	74	2,975 ^{a}	61
Poult Excreta $aAME_n$	2,611 ^{ab}	90	2,534 ^{a}	74	3,004 ^{a}	61
Significance	0.0007		NS		<0.0001	

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

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

Sample	**mbm-7**		**mbm-8**		**mbm-9**	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TME_n	3,329 ^{a}	131	2,547 ^{a}	86	3,356 ^{a}	97
Turkey TME_n	3,103 ^{ab}	131	2,585 ^{a}	86	2,669 ^{b}	97
Chick Digesta AME_n	2,705 ^{b}	131	2,401 ^{a}	97	2,858 ^{b}	86
Chick Excreta AME_n	3,038 ^{ab}	131	2,552 ^{a}	86	3,003 ^{ab}	86
Chick Excreta $aAME_n$	3,081 ^{ab}	131	2,594 ^{a}	86	3,040 ^{ab}	86
Poult Digesta AME_n	2,863 ^{ab}	131	2,581 ^{a}	97	2,946 ^{ab}	137
Poult Excreta AME_n	2,888 ^{ab}	131	2,503 ^{a}	86	2,822 ^{b}	86
Poult Excreta $aAME_n$	3,103 ^{ab}	131	2,530 ^{a}	86	2,851 ^{b}	86
Significance	0.0579		NS		0.0017	

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

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

Table 7. Mean Metabolizable Energy Values for each Assay Method of each Meat and Bone Meal Product (kcal/kg)

Sample	**mbm-10**		**mbm-12**		**mbm-13**	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TME_n	2,685 [a]	118	1,703 [b]	78	2,282 [a]	107
Turkey TME_n	2,789 [a]	152	2,192 [a]	78	2,010 [a]	107
Chick Digesta AME_n	2,737 [a]	118	1,813 [b]	78	2,385 [a]	107
Chick Excreta AME_n	2,820 [a]	118	2,168 [a]	78	2,013 [a]	107
Chick Excreta $aAME_n$	2,861 [a]	118	2,204 [a]	78	2,052 [a]	107
Poult Digesta AME_n	2,891 [a]	118	1,872 [ab]	78	2,330 [a]	107
Poult Excreta AME_n	2,791 [a]	118	1,975 [ab]	78	2,115 [a]	107
Poult Excreta $aAME_n$	2,811 [a]	118	1,999 [ab]	78	2,137 [a]	107
Significance	NS		0.0004		NS	

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

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

Sample	**mbm-14**		**mbm-15**		**mbm-16**	
	Mean[1]	SE[2]	Mean[1]	SE[2]	Mean[1]	SE[2]
Rooster TME_n	2,267 [a]	109	2,858 [ab]	135	2,106 [a]	122
Turkey TME_n	2,355 [a]	97	2,583 [ab]	120	1,854 [a]	136
Chick Digesta AME_n	1,953 [a]	97	2,474 [b]	120	1,945 [a]	122
Chick Excreta AME_n	2,332 [a]	97	3,079 [a]	120	1,588 $_a$	122
Chick Excreta $aAME_n$	2,369 [a]	97	3,123 [a]	120	1,623 $_a$	122
Poult Digesta AME_n	2,067 [a]	97	2,785 [ab]	135	2,019 [a]	122
Poult Excreta AME_n	2,325 [a]	97	2,932 [ab]	120	2,017 [a]	136
Poult Excreta $aAME_n$	2,355 [a]	97	2,974 [ab]	120	2,045 [a]	136
Significance	NS		0.0062		NS	

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

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

**** Rooster/Turkey TME – Precision fed assay

Chick/poult digesta AME- collection of gut contents

Chick/poult excreta AME- collection of excreta from pans

Chick/poult excreta aAME- collection of excreta from pans adjusted for endogenous loss

Table 8.Mean Metabolizable Energy Comparisons for Meat and Bone Meal Products (kcal/kg)

System	Mean[1]	SE[2]	Significance
ME[3]	2,511 [a]	24	NS
TME[3]	2,487 [a]	42	
Collection	**Mean[1]**	**SE[2]**	**Significance**
Digesta[4]	2,409 [b]	41	0.011
Excreta[4]	2,560 [a]	29	
Total[4]	2,487 [ab]	42	
Species	**Mean[1]**	**SE[2]**	**Significance**
Chicken	2,501 [a]	29	NS
Turkey	2,509 [a]	30	

[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 9. Mean Metabolizable Energy Values for each Meat and Bone Meal Product (kcal/kg)

MBM Sample	Mean[1,3]	SE[2]
2	2,518 [c]	47
3	2,514 [c]	46
5	2,781 [ab]	47
7	2,981 [a]	46
8	2,503 [c]	46
9	2,876 [ab]	47
10	2,758 [b]	47
12	1,984 [ef]	46
13	2,165 [de]	46
14	2,245 [d]	47
15	2,827 [ab]	47
16	1,894 [f]	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.

Prediction equations generated from the above data are below:

MBM: $ME_n = 240.8 - 75.9*(CHO) + 47.8*(CP)$ ($R^2 = 0.42$, using proximates)

MBM: $ME_n = -978 - 59.3*(CHO) + 0.9*(GE)$ ($R^2 = 0.77$, using Gross energy)

Practical use of animal fats

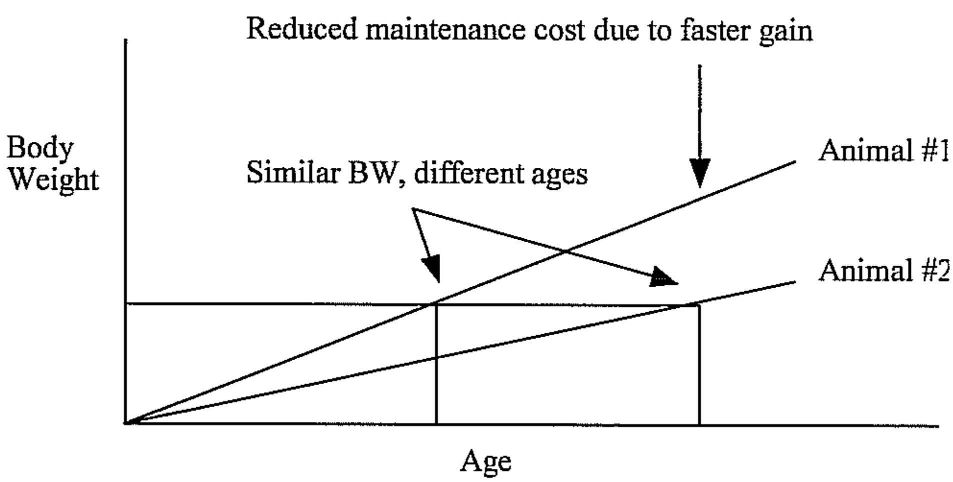
Use of fats for animal feed has many advantages. In the author's opinion, we tend to feed diets too low in energy and should probably utilize higher levels of energy based on pricing structures in most cases. Some of the benefits of fat addition are noted below as well as some concerns:

-Concentrated source of energy and the main method of increasing the energy content of diets
-Increases growth rates
-Increases feed efficiency
-Decreases feed intake
-Source of linoleic acid
-Decreases dustiness of feeds and reduces dust losses
-Lubricant for equipment in feedmills
-Increases palatability of feeds
-Increased rate of gain can decrease age at market and increase throughput of housing systems
-Lower heat increment is useful during heat stress to keep caloric intake up
-May slow gut transit of other feeds, resulting in increased digestibility
-May show an 'extracaloric' effect
-May be more cost effective than other energy sources
-Concentrated feeds can decrease transportation costs for feed delivery
-Use of higher levels of fat may negate the effects of pelleting

Some concerns that should be noted with fat utilization:

-Measurement of Metabolizable Energy (ME) content can be somewhat difficult
-Potential for rancidity thus use quality products
-Equipment needs relative to fat additions must be adequate
-Poor digestibility of saturated fats by the young bird

While this article is not intended to be a treatise on fat utilization, the graph below illustrates the principle behind much of the beneficial effects of fat. Basically what the graph shows is that as we increase growth rate (through increased energy intake for instance) that we reduce our total costs for maintenance and thus improve efficiency.



Summary

Animal by-products as a group represent viable feed ingredients at prices that have traditionally been considered normal. When prices such as are found at the time of this writing for ruminant meat and bone meal occur, they can be a source of considerable cost savings for the poultry industry.

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