RENDERED PRODUCTS IN SWINE NUTRITION

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Summary

Numerous rendered products can be used in swine diets. In general, these by-products of the packing/rendering industry are good sources of amino acids, calcium, phosphorus, and other minerals, as well as B-complex vitamins. The major animal-derived by-products used in swine diets are meat meal, meat and bone meal, fish meal, dried blood products (blood meal, spray-dried plasma, and spray-dried blood cells), steamed bone meal, and rendered animal fats (tallow, grease, and mixtures of animal fats). Small amounts of poultry by-product meal and hydrolyzed feather meal are also use, but to a lesser extent. This chapter gives an overview of the composition of these products and their nutritional value for swine.

Introduction

Pig production represents an important segment of the food animal industry in the United States and throughout the world. Pork is an important source of protein for humans and is the most widely consumed meat in the world today. Today's pork is lean and supplies many essential nutrients to consumers.

Swine are produced in many types of operations from small farms to huge and highly integrated corporations. Today's pork is produced by fewer producers than ever before, and the operations are much larger than they were in the past. Table 1 illustrates that approximately 78 percent of the pork in the United States is produced by only 1.5 percent of pig farms, and these farms are quite large, having an annual production of at least 10,000 market pigs, and for some mega-farms, over 500,000 market pigs annually.

Table 1. Number of Swine Operations in the United States by Size and the Market Share of the Pigs that are Produced on These Farms - 2003[a].

No. of Pigs Marketed Annually	No. of Pig Farms	Percent of All Pig Farms	% Market Share
Less than 1,000	59,950	85.5	1
1,000 to 3,000	6,630	9.5	8
3,000 to 5,000	950	1.4	4
5,000 to 10,000	1,526	2.2	9
10,000 to 50,000	915	1.3	19
50,000 to 500,000	134	0.2	19
More than 500,000	25	0.04	40

[a] National Pork Board, 2006.

Regardless of the size of operations or the types of facilities in which pigs are raised, a sound nutrition and feeding program is necessary for the operation to be profitable. Because feed represents 65 to 75 percent of the total cost of production, swine producers must have a good understanding of the nutrient requirements of pigs, a knowledge of the feedstuffs that can be used in pig feed, and an appreciation for sound feeding management in order for them to produce pigs efficiently and economically.

Pigs are unique in that they have the ability to obtain nutrients from a wide variety of feedstuffs. Swine are omnivorous; that is, they consume both plant and animal food sources. In today's operations, the major feedstuffs are vegetative in nature (predominately cereal grains and oilseed meals) with corn and soybean meal representing 80 percent or more of the total feedstuffs fed to swine. However, feedstuffs from animal sources also are commonly included in commercial swine diets. The majority of these animal-derived feedstuffs are by-products of the meat packing/rendering industry. Many of them by-products have unique properties that enhance the feeding program of pigs.

Overview of Swine Nutrition

An overview of the fundamentals of swine nutrition and feeding will help one to understand and have an appreciation for the use of animal-derived rendered products and other feedstuffs in swine diets.

Pigs require more than 40 individual nutrients in their diet in order to sustain life, grow rapidly, and reproduce and lactate efficiently. Some of these nutrients are present in adequate amounts in normally consumed feedstuffs (cereal grains, oilseed meals, etc.), and those that are deficient can be easily supplemented from concentrated or synthetic sources. The best estimates of the quantitative requirements for all of these nutrients can be found in the publication *Nutrient Requirements of Swine*, published by the National Research Council (NRC, 1998).

Nutrients are traditionally grouped into six classes: water, carbohydrates, fats, protein, minerals, and vitamins. Water is often considered to be the most important nutrient because animals cannot live very long without it. Carbohydrates, fats, and protein provide energy for animals. In addition, protein supplies amino acids that are essential for growth, reproduction, and lactation. Minerals and vitamins have numerous important roles in the body.

Energy

Energy is required for all functions in the life process. For pigs, energy is derived primarily from carbohydrates and fats, and to a certain extent, from protein. Energy is classified as digestible energy (DE), metabolizable energy (ME), or net energy (NE). The DE content of a feed represents the energy that is digested (energy in feed minus energy in feces). The ME content of a feed represents the DE less any energy lost in the urine and in fermentation gasses. The NE of a feed is the ME less the heat expended to digest and utilize the feedstuff. DE and ME are more easily determined than NE, and because of a larger database, DE and ME are more commonly used in the United States.

Pigs are simple-stomached animals, so they must rely on feeds having readily digestible carbohydrates, such as starch and sugars, to meet their energy needs. Ruminant animals depend on microorganisms in their rumen to degrade cellulose, hemicellulose, and other complex carbohydrates found in roughages into fermented products that can be absorbed and utilized. However, pigs cannot do this efficiently. Some fermentation does occur in the hind gut of more mature swine, but the process is much less efficient than in ruminants.

Cereal grains are high in starch and they constitute the major part of modern swine diets. Almost all of the starches in corn and other cereal grains are digested by pigs. The end product of starch digestion is glucose, which is readily absorbed and utilized as an energy source. Sugars, such as lactose in milk and milk products, represent an important energy source for weanling pigs. The sugar, sucrose, in sugar cane and sugar beets also is well utilized by pigs, but these feed sources are not widely used in the United States.

Fats and oils are also highly digestible energy sources for pigs. In addition, the energy in fats and oils is approximately 2.3 times as concentrated as the energy in an equivalent amount of carbohydrates. Thus, supplemental fat represents an efficient way of increasing the energy concentration of the diet. Because pigs tend to eat an amount of feed that will meet their energy requirement, adding fat to the diet will reduce feed intake and substantially improve the feed-to-gain ratio. Supplemental fat also has other beneficial properties (reduced dustiness, etc.), which will be discussed later in the chapter.

Protein in the diet that is in excess of the requirement for the various amino acids can be used as an energy source, but it is too costly to be fed solely for energy. The energy contribution of various rendered animal products is shown in Table 2.

Protein

Body protein consists of 22 amino acids. About one-half of the body protein is in the muscle tissues and the remaining protein is in the organs, viscera, blood, and hair. A small amount is in the enzymes and other digestive secretions as well as the hormones of the body. For protein synthesis (i.e., growth) to occur, the diet must supply sufficient amounts of 10 of the 22 amino acids; these are called "essential" amino acids. The other 12 amino acids, called "non-essential" amino acids, can be synthesized by pigs as long as sufficient nitrogen is present in the diet.

Because pigs are simple-stomached, they must rely on amino acids from dietary sources to meet their essential amino acid requirements. In other words, pigs cannot rely on microbes to synthesize the essential amino acids such as the case with ruminants. Therefore, dietary protein must be in a form that is readily digestible (so as to liberate the amino acids from the protein), and the pattern of liberated amino acids must supply adequate amounts of the 10 essential amino acids. A deficiency of any one of the 10 amino acids will limit pig performance.

The amino acid that is most likely to be deficient in most diets consisting of various combinations of feedstuffs is lysine. This is due to two reasons: first, because lysine is the most abundant of all the amino acids in the body (about 7 percent lysine in whole body protein); and second, because many of the feedstuffs (especially cereal grains) are extremely low in lysine.

Table 2. Dry Matter, Energy, and Fat Composition of Rendered Animal Products and Dehulled Soybean Meal[a].

Feedstuff	Dry Matter %	Digestible Energy kcal/lb	Metabolizable Energy kcal/lb	Net Energy kcal/lb	Fat %
Meat meal	94	1,224	1,178	987	12.0
Meat and bone meal	93	1,108	1,010	615	10.9
Poultry by-product meal	93	1,403	1,298	883	12.6
Feather meal, hydrolyzed	93	1,357	1,128	1,022	4.6
Fish meal, menhaden	92	1,712	1,525	1,060	9.4
Blood meal, ring dried	93	1,530	1,337	940	1.3
Plasma, spray dried	91	--	--	--	2.0
Blood cells, spray dried	92	--	--	--	1.5
Steamed bone meal					
Animal fat					
Beef tallow		3,632	3,487	2,236	
Choice white grease		3,764	3,612	2,313	
Lard		3,761	3,609	2,315	
Poultry fat		3,868	3,714	2,374	
Restaurant grease		3,882	3,725	2,381	
Soybean meal, dehulled	90	1,673	1,535	917	3.0

[a] NRC, 1998.

Protein sources for swine are generally characterized on the basis of their "protein quality," which refers to the amino acids in the protein. Milk proteins have the highest quality protein in that the profile of their amino acids closely matches that of the needs of pigs. The protein in some oilseed meals and rendered animal products is considered intermediate to high in protein quality, but the quality of protein is low in certain other sources. The protein in cereal grains is of very poor quality due to low concentrations of lysine, tryptophan, and threonine. Interestingly, soybean meal by itself is low in methionine, but when combined with cereal grains (which are relatively higher in methionine); the quality of protein is much improved.

The amino acids in feed protein are not totally digested and absorbed by pigs; in other words, the bioavailability of amino acids in intact protein is not 100 percent. However, the availabilities of most of the amino acids are within the range of 70 to 90 percent. The availability of amino acids in individual feedstuffs to the animal is determined by the disappearance of amino acids at the end of the small intestine in ileal-cannulated pigs, and is referred to as "ileal digestibility." The digestibility can be express as "apparent" or a "true" ileal digestibility. The latter corrects for endogenous amino acids (non-feed sources of amino acids such as enzymes, mucus, eroded epithelial cells, etc.). The "digestible amino acid" system is commonly used today in the U.S. feed industry.

Minerals and Vitamins

Pigs require 14 minerals in their diet. Some of these minerals (sulfur, magnesium, potassium, chromium) are provided in sufficient supply by the natural ingredients, but others must be supplemented. Calcium, phosphorus, salt (sodium, chloride), and the trace minerals, copper, iron, manganese, zinc, iodine, and selenium, are commonly added to most grain-soybean meal diets, but significant amounts of some of these minerals can be partially or evenly totally supplied by rendered animal products.

Calcium and phosphorus are required in greater amounts than any other minerals. Pigs require significant amounts of both minerals for bone formation and for many other purposes. Most plant-derived feedstuffs are extremely low in calcium and much of the phosphorus is organically bound in a form called phytic acid (or phytate) that is unavailable to pigs. Because of the low bioavailability of phosphorus in plant-derived feedstuffs (Cromwell and Coffey, 1993), grain-oilseed based diets need rather large amounts of highly available calcium (usually as ground limestone) and phosphorus (as mono- or dicalcium phosphate, defluorinated phosphate, or steamed bone meal) to meet the requirement. Much, or even all, of the calcium and phosphorus requirements can be provided by certain animal-derived protein sources (discussed later in the chapter).

Common salt, added at 0.25 to 0.50 percent, will meet the sodium and chlorine requirements of pigs. The other major minerals – magnesium, potassium, and sulfur – are provided in sufficient amounts by the natural ingredients. The trace minerals are commonly included in diets in the form of a trace mineral premix.

Thirteen vitamins are required by swine. Vitamins A, D, E, K, and B_{12} along with riboflavin, pantothenic acid, and niacin are commonly added to swine diets. Three additional vitamins – biotin, folic acid, and choline – are often added to sow diets. The other two essential vitamins, thiamin and pyridoxine (vitamin B_6), are supplied in sufficient quantities by the natural ingredients and do not have to be supplemented. Additions of the B-complex vitamins is less critical when rendered animal products constitute a portion of the protein supplement because animal protein sources contain much higher levels of these vitamins, as well as trace minerals, than do oilseed meals. In the past, several high-protein feeds were blended with legume products as supplements for cereal grains to meet the vitamin and trace mineral requirements of pigs. Today, synthetically-produced vitamins and inorganic (or organic) trace minerals are commonly included as premixes to supplement these important micronutrients to swine feeds.

Rendered Animal Protein Sources for Swine

In general, animal protein supplements are good sources of lysine and the other amino acids. In addition, they contain higher levels of minerals and B-complex vitamins than plant protein sources. However, animal protein supplements tend to be more variable in nutrient content, and they are subjected to high drying temperatures during processing for dehydration and sterilization. Unless carefully controlled, high temperatures can reduce the bioavailability of certain amino acids.

Typical amino acid composition of the more common animal protein sources for swine is shown in Table 3 and estimates of the apparent and true ileal digestibility of amino acids in these protein sources are given in Tables 4 and 5. The calcium, phosphorus, and bioavailable phosphorus levels in these feedstuffs are shown in Table 6. Nutrient levels in dehulled soybean meal are also given in these tables for comparative purposes. All of the values are from the National Research Council's *Nutrient Requirements of Swine* (NRC, 1998).

Table 3. Protein and Amino Acid Composition of Rendered Animal Products and Dehulled Soybean Meal[a] (Percent).

Feedstuff	Prot.	Lys	Thr	Trp	Met	Cys	Ile	Val
Meat meal	54.0	3.07	1.97	0.35	0.80	0.60	1.60	2.66
Meat and bone meal	51.5	2.51	1.59	0.28	0.68	0.50	1.34	2.04
Poultry by-product meal	64.1	3.32	2.18	0.48	1.11	0.65	2.01	2.51
Feather meal, hydrolyzed	84.5	2.08	3.82	0.54	0.61	4.13	3.86	5.88
Fish meal, menhaden	62.3	4.81	2.64	0.66	1.77	0.57	2.57	3.03
Blood meal, ring dried	88.8	7.45	3.78	1.48	0.99	1.04	1.03	7.03
Plasma, spray dried	78.0	6.84	4.72	1.36	0.75	2.63	2.71	4.94
Blood cells, spray dried	92.0	8.51	3.38	1.37	0.81	0.61	0.49	8.50
Soybean meal, dehulled	47.5	3.02	1.85	0.65	0.67	0.74	2.16	2.27

[a] NRC, 1998.

Table 4. Apparent Ileal Digestibility of Amino Acids in Rendered Animal Products and Dehulled Soybean Meal[a].

Feedstuff	Lys	Thr	Trp	Met	Cys	Ile	Val
Meat meal	83	79	73	85	55	82	79
Meat and bone meal	74	70	60	79	55	74	74
Poultry by-product meal	78	72	74	74	70	77	74
Feather meal, hydrolyzed	54	74	63	65	71	81	80
Fish meal, menhaden	89	85	79	88	73	87	85
Blood meal, ring dried	91	86	88	85	81	71	90
Plasma, spray dried	87	82	92	64	--	85	86
Blood cells, spray dried	--	--	--	--	--	--	--
Soybean meal, dehulled	85	78	81	86	79	84	81

[a] NRC, 1998.

Table 5. True Ileal Digestibility of Amino Acids in Rendered Animal Products and Dehulled Soybean Meal[a].

Feedstuff	Lys	Thr	Trp	Met	Cys	Ile	Val
Meat meal	83	82	79	87	58	84	80
Meat and bone meal	80	80	78	83	63	82	79
Poultry by-product meal	80	77	--	77	72	81	74
Feather meal, hydrolyzed	67	82	86	74	73	88	84
Fish meal, menhaden	95	88	90	94	88	94	93
Blood meal, ring dried	94	94	94	96	91	88	91
Plasma, spray dried	--	--	--	--	--	--	--
Blood cells, spray dried	--	--	--	--	--	--	--
Soybean meal, dehulled	90	87	90	91	87	89	88

[a] NRC, 1998.

Table 6. Calcium, Phosphorus, and Bioavailable Phosphorus Composition of Rendered Animal Products and Dehulled Soybean Meal[a].

Feedstuff	Calcium %	Phosphorus %	Phosphorus Availability[b] %	Available Phosphorus[c] %
Meat meal	7.69	3.88	90[d]	3.49
Meat and bone meal	9.99	4.98	90	4.48
Poultry by-product meal	4.46	2.41	90[d]	2.17
Feather meal, hydrolyzed	0.33	0.50	31	0.16
Fish meal, menhaden	5.21	3.04	94	2.86
Blood meal, ring dried	0.41	0.30	92	0.28
Plasma, spray dried	0.15	1.71	95[d]	1.62
Blood cells, spray dried	0.02	0.37	95[d]	0.35
Steamed bone meal	29.80	12.50	85	10.63
Soybean meal, dehulled	0.34	0.69	23	0.16

[a] NRC, 1998.
[b] Percent of the phosphorus that is bioavailable to pigs.
[c] Total phosphorus times percent of the phosphorus that is bioavailable.
[d] Estimated.

Other reviews of animal protein sources have been written by Cunha (1977), Thacker and Kirkwood (1990), Knabe (1991), Chiba (2001), Cromwell (2002), and McGlone and Pond (2003).

Meat Meal, Meat and Bone Meal

Meat meal and meat and bone meal are the two most common animal protein sources used in swine diets. Both of these by-products have been widely used in swine feeds for many years (Franco and Swanson, 1996). These products are officially described as the rendered product from mammalian tissues including bone, but exclusive of any added blood, hair, hoof, horn, hide trimmings, manure, stomach, and ruminal contents, except such amounts as may occur unavoidably in good processing practices (AAFCO, 2006). The amount of phosphorus is the main criterion for distinguishing the two products. If the phosphorus level is 4.0 percent or greater, the product is designated as meat and bone meal. If the phosphorus level is less than 4.0 percent, the product is designated as meat meal. According to the official definition, the calcium level should not be more than 2.2 times the phosphorus level. Although not included in the official definition, crude protein of meat and bone meal is approximately 50 percent and meat meal is approximately three to five percentage units higher in protein. Meat meal tankage and meat and bone meal tankage are similar to meat meal or meat and bone meal, respectively except that they also contain blood or blood meal.

For most feedstuffs, the percentages of the various amino acids tend to increase as the level of crude protein in the feedstuff increases; however the correlation between the two is often relatively poor. An analysis of 73 samples of meat meal and meat and bone meal (Knabe, 1995), showed that lysine increased by 0.06 percent for each one percent increase in crude protein ($R^2 = 0.47$, Figure 3).

The lysine in meat meal is as high as, and even slightly higher than, the lysine in soybean meal (Table 3). However, the bioavailability of the lysine is slightly less than that in soybean meal (Tables 4 and 5). Both meat meal and meat and bone meal are relatively low in tryptophan and some research has shown that the bioavailability (i.e., ileal digestibility) of tryptophan and some of the other amino acids is a bit low (Knabe, 1987; NRC, 1998). The low tryptophan content is due to the fact that collagen is one of the major proteins in bone, connective tissue, cartilage, and tendons (Eastoe and Eastoe, 1954), and collagen is nearly void of tryptophan (Eastoe and Long, 1960).

Figure 1. Relationship of Calcium and Phosphorus in 426 Samples of Meat Meal and Meat and Bone Meal (Adapted from Knabe, 1995).

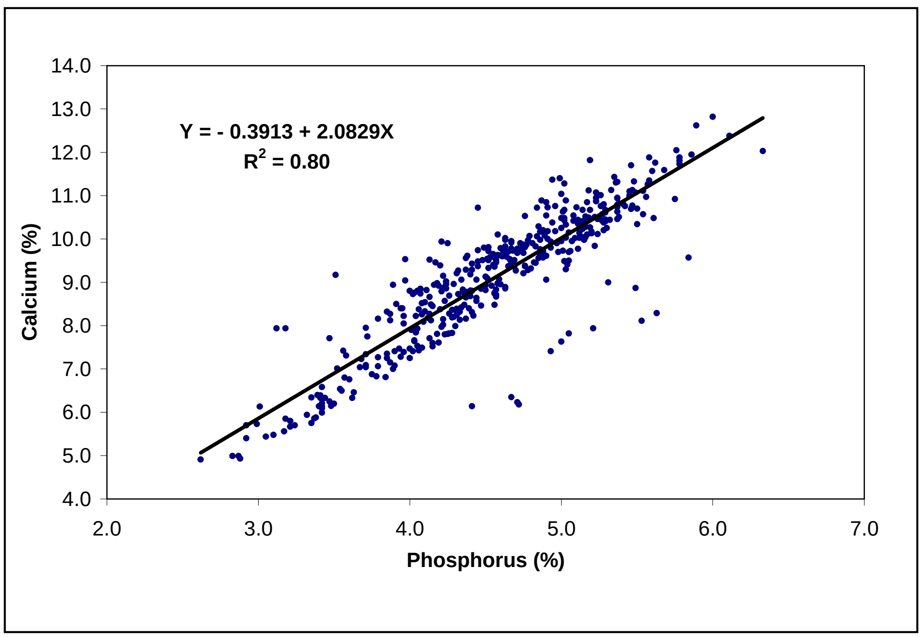


Figure 2. Relationship of Crude Protein and Phosphorus in 426 Samples of Meat Meal and Meat and Bone Meal (Adapted from Knabe, 1995).

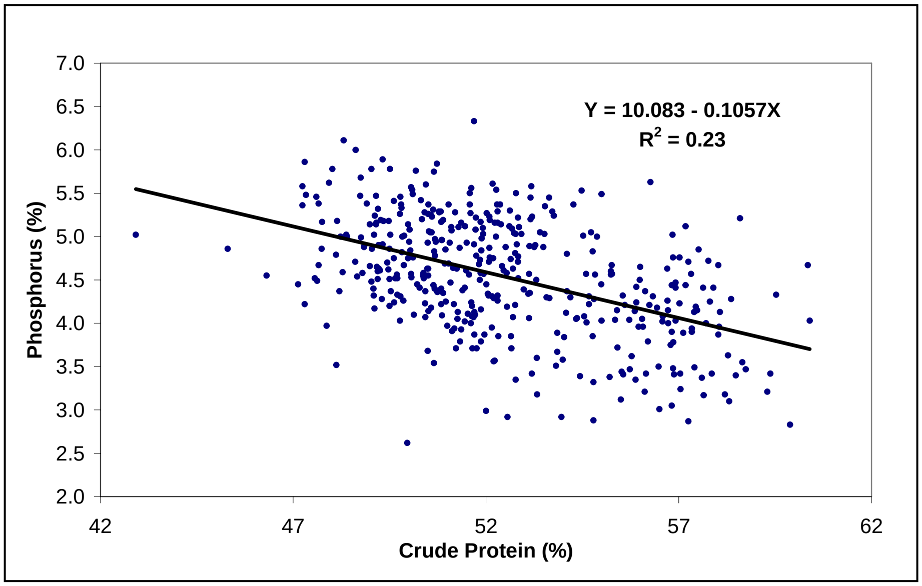
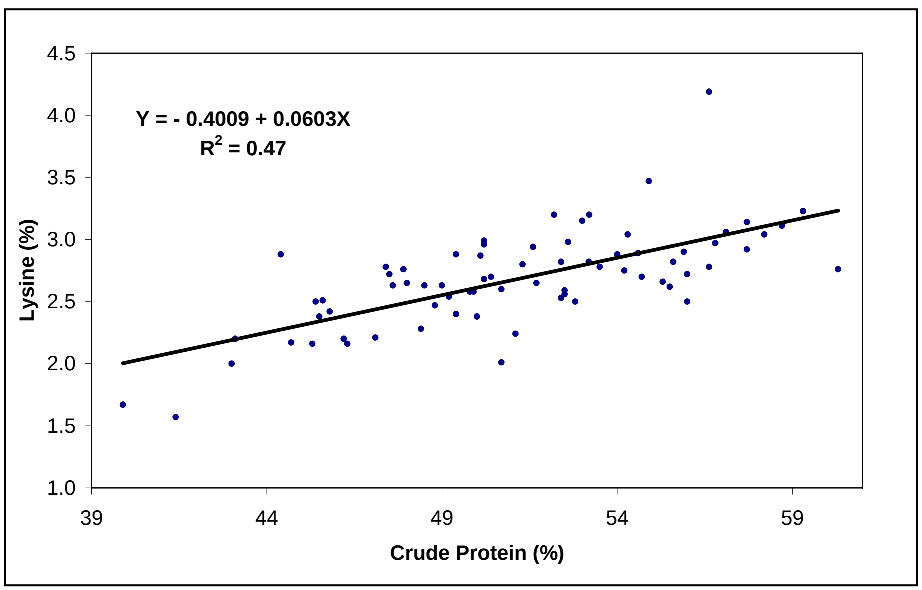


Figure 3. Relationship of Crude Protein and Lysine in 73 Samples of Meat Meal and Meat and Bone Meal (Adapted from Knabe, 1995).



Knabe (1995) summarized the composition of 426 samples of meat meal and meat and bone meal and found that they averaged 52.4 percent protein, 9.07 percent calcium, and 4.54 percent phosphorus (Table 7). The average fat content of 113 samples was 10.68 percent. A regression analysis of the data summarized by Knabe (1995) indicated a very strong linear relationship between calcium and phosphorus in meat meal and meat and bone meal (R^2 = 0.80), with calcium increasing 2.08 percent for every one percent increase in phosphorus (Figure 1). A further analysis of the data summarized by Knabe (1995) indicated that the phosphorus decreased by 0.106 percent for each one percent increase in crude protein (R^2 = 0.23, Figure 2).

Table 7. Composition of Meat Meal and Meat and Bone Meal Analyzed by Three Feed Manufacturers[a].

Feedstuff	No. Samples	Crude Protein %	Calcium %	Phosphorus %	Crude Fat[b] %
Meat meal	171	54.0 ±2.93	7.69 ±1.16	3.88 ±0.41	10.72 ±1.55
MBM	255	51.4 ±2.64	9.99 ±1.01	4.98 ±0.38	10.70 ±1.61
All meals	426	52.4 ±3.04	9.07 ±1.56	4.54 ±0.67	10.68 ±1.58

[a] Knabe, 1995. As fed basis. All samples were sold as meat and bone meal. In this summary, meat meal represents samples having < 4.0% phosphorus.
[b] Crude fat was based on 35 samples of meat meal and 78 samples of meat and bone meal.

Some of the early feeding experiments with meat and bone meal indicated that growth performance was reduced in growing-finishing pigs when increasing levels of meat and bone meal was substituted for soybean meal in corn-based diets (Peo and Hudman, 1962; Evans and Leibholz, 1979). These early studies indicated that the maximum amount of meat meal or meat and bone meal should not exceed two to three percent of the diet. However, more recent studies at the University of Kentucky have shown that higher levels of meat meal or meat and bone meal can be included in growing-finishing diets for swine without reducing performance if tryptophan is also supplemented (Cromwell et al., 1991). The studies showed that when 0.03 percent tryptophan was added for every 10 percent addition of meat and bone meal in the diet, performance was nearly as good as for pigs fed corn-soybean meal diets (Table 8). The studies involved 24 pigs per treatment from 53 to 205 lb body weight in Experiment 1 and 20 pigs per treatment from 99 to 207 lb body weight in Experiment 2. The relatively high levels of calcium and phosphorus in meat meal and meat and bone meal allow diets to be formulated for swine without having to include inorganic calcium and phosphorus supplements. Recent studies at the University of Kentucky indicated that the phosphorus in meat and bone meal was 85 to 91 percent as bioavailable as the phosphorus in mono- or dicalcium phosphate (Traylor et al., 2005ab). Inclusion of sufficient amounts of meat and bone meal to met the calcium and phosphorus requirements of growing-finishing pigs in their study resulted in optimal performance and bone integrity (Table 9).

Table 8. Levels of Meat and Bone Meal in Corn-Soybean Meal Diets on Performance of Growing-Finishing Pigs[a].

	Meat and Bone Meal in Diet, Percent				
	0	5	5	10	10
Item	Added Tryptophan, %				
	-	-	0.015	-	0.030

Experiment 1					
Daily gain, lb	1.51	1.38	1.47	1.05	1.43
Daily feed, lb	4.97	4.80	4.93	3.96	4.93
Feed/gain	3.30	3.50	3.37	3.79	3.45
Experiment 2					
Daily gain, lb	1.89	-	-	1.10	1.80
Daily feed, lb	6.89	-	-	5.10	6.51
Feed/gain	3.65	-	-	4.67	3.60

[a] Cromwell et al., 1991.

Table 9. Performance of Finishing Pigs Fed Diets with the Supplemental Calcium and Phosphorus Supplied by Dicalcium Phosphate or Meat and Bone Meal[a].

	Source of Phosphorus			
	Dicalcium Phosphate		Meat and Bone Meal	
Dietary calcium, %	0.50	0.65	0.55	0.65
Dietary Phosphorus, %	0.45	0.55	0.45	0.55
Daily gain, lb	1.87	1.94	1.96	1.96
Feed/gain	3.10	3.15	3.05	3.03
Lean gain, g/day	330	337	333	332
Bone strength, kg[b]	178	194	182	194
Carcass lean, %	53.1	52.6	52.6	52.4

[a] Traylor et al., 2005a. Study involved 25 pigs per treatment from 99 to 242 lb body weight. These levels of calcium and phosphorus were fed during the first half of the finishing period, then calcium was reduced to 0.45 or 0.55% and phosphorus was reduced to 0.40 or 0.50%, respectively.
[b] Main effect of phosphorus level ($P < 0.05$).

Questions are often asked as to what factors may affect the nutritional value of meat meal and meat and bone meal for pigs. Certainly overheating of the meals during processing has been shown to reduce the bioavailability of several of the amino acids (Batterham et al., 1986; Knabe, 1987). However, excessive heating of meals does not appear to reduce the bioavailability of phosphorus according to the Traylor et al. (2005b) studies. Similarly, particle size of the meal within ranges commonly used in the industry does not affect the bioavailability of phosphorus

(Traylor et al., 2005b). On the other hand, the phosphorus in a high-ash, meat and bone meal of bovine origin was found by these researchers to be more bioavailable than the phosphorus in a low-ash meat meal of porcine origin, a difference of approximately 15 percentage units. The researchers proposed that the difference in phosphorus bioavailability may have been due to a greater proportion of the phosphorus in the high-ash meal being supplied by bone whereas more of the phosphorus in the low-ash meal was supplied by soft tissues.

Poultry By-product Meal

Poultry by-product meal is a rendered product from poultry slaughter and processing plants. It is officially described as the ground, rendered, or clean parts of slaughtered poultry such as head, feet, undeveloped eggs, and intestines, exclusive of feathers except in such amounts as might occur unavoidably in good processing practices (AAFCO, 2006). Because most of the poultry industry is so vertically integrated, this product generally goes back into the companies' own poultry feed, and much less of this product is used in the swine feeds as compared with meat meal or meat and bone meal. The amino acid composition of poultry by-product meal is not greatly different from that of meat meal or meat and bone meal, but it is somewhat lower in calcium and phosphorus than the mammalian products. With respect to feeding studies with swine, very little research has been done with poultry by-product meal.

Hydrolyzed Feather Meal

Feather meal has a similar composition as poultry feathers. This product is very high in protein (85 percent crude protein), but the quality of the protein is poor due to the high content of cystine relative to the other amino acids. Hydrolysis of the feathers is required to break the many sulfur bonds and release the amino acids. Even then, the apparent and true ileal digestibility of lysine and other amino acids is low compared with other rendered products. Much of the feather meal goes back into poultry feeds. Some research has shown that swine can use a limited amount of hydrolyzed feather meal in their diets, but use in the swine industry is relatively uncommon. Chiba (2001) has reviewed several research studies with pigs that involved the feeding of hydrolyzed feather meal.

Fish Meal

Fish meal is officially described as the clean, dried, and ground tissues of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil (AAFCO, 2006). Fish meal is an excellent protein source for pigs; however, the high cost of fish meal in the United States limits its use in most diets. The major producers of fish meal are Peru and Chili. Most of the fish meal used in swine feed is used in starter diets for weanling pigs. Fish meals are quite variable in composition, depending on the type of fish used and the type of processing methods. Some meals are made from residues and others are made from the whole fish. Menhaden fish meal is a high-oil fish meal and is the one most commonly used in starter diets. Inclusion of select menhaden fish meal or fish solubles in starter diets has been shown to improve performance of early-weaned pigs in several studies (Stoner et al., 1990; Seerley, 1991). Certain long-chained fatty acids in fish oil can cause a "fishy" flavor in pork, so the level of fish meal should not exceed six to seven percent. In finisher diets, even lower levels can result in an undesirable "fishy" flavor in pork meat products.

Blood Products for Swine

Dried Blood Meal

Dried blood meal is very high in protein (85 to 90 percent) and in lysine (seven to eight percent). Some of the older methods used to dry blood meal destroyed much of lysine and some of the other amino acids and reduced palatability (Chiba, 2001); thus, blood meal was not used to any great extent in swine diets in the past. However, improved methods of drying, including ring drying and flash drying, results in a much improved product with a high level of available lysine and other amino acids (Parsons et al., 1985; Miller, 1990). Blood meal is very low in isoleucine, the first limiting amino acid in a corn-blood meal blend. Because of the high level of hemoglobin in blood meal, the iron content is very high (1,900 to 2,900 ppm; NRC, 1998).

Several studies have shown that properly dried blood meal is a good protein source when used at low levels in pig diets (Miller, 1990; Hansen et al., 1993; Kats et al., 1994). Generally, it is recommended that dried blood meal should be limited to one to four percent of the pig diet (Cunha, 1977; Wahlstrom and Libal, 1977; Miller, 1990), although higher levels (six to eight percent) have also been suggested (Seerley, 1991).

Dried Animal Plasma and Dried Blood Cells

Two relatively new products that are extensively used in prestarter and starter diets for early weaned pigs are made from blood from pig and cattle slaughter plants. The blood is treated with an anticoagulant (sodium citrate), stored under refrigeration, separated into plasma and blood cells, and carefully spray-dried. Spray-dried animal plasma is an excellent protein source for early-weaned pigs. Aside from its superior amino acid profile (Table 3), the high levels of globular proteins (including immunoglobulins) in dried animal plasma stimulate growth and feed intake during the critical postweaning stage. A recent study at the University of Kentucky (Pierce et al., 2005) verified that the immunoglobulins, primarily immunoglobulin G, are the major component in plasma that stimulates growth in early-weaned pigs. Furthermore, plasma from either cattle or swine blood seem to be equally effective in producing this response (Pierce et al., 2005). Spray-dried animal plasma, although relatively expensive, is now commonly used at levels of three to six percent in Phase I pig starters for the first one to two weeks following weaning. A review by Coffey and Cromwell (2001) summarized the value of this product in weanling pig diets.

Dried blood cells, the product that remains after plasma is removed from blood is also an excellent ingredient for pig starter diets. Generally, this product is used at levels of two to five percent in Phase II diets for weanling pigs, following the removal of the more expensive dried plasma from the diet. Blood cells are very high in lysine, but relatively low in isoleucine. In addition, the iron content of dried blood cells is quite high (2,700 ppm; NRC, 1998) due to the high concentration of hemoglobin in the product. A review of feeding studies with dried blood cells was written by Coffey and Cromwell (2001).

Steamed Bone Meal – A Mineral Source for Swine

Steamed bone meal is one of several mineral supplements that are used in the feed industry as sources of calcium and phosphorus. This product is made from bones cooked under steam pressure, then dried and ground. The calcium and phosphorus levels in bone meal are in the same ratio as found in bone (Table 6). Due to its higher cost and slightly lower bioavailability of phosphorus for swine (82 to 85 percent versus 95 to 100 percent for dicalcium phosphate; Cromwell and Coffey, 1993), steamed bone meal is not as commonly used as a phosphorus supplement for swine as mono- or dicalcium phosphate or defluorinated phosphate.

Rendered Animal Fats – An Energy Source for Swine

Animal fats are widely used in swine feeds. Rendered animal fats – inedible tallow, inedible grease, and poultry fat – represent approximately 60 percent of the fats and oils fed to livestock and poultry, whereas restaurant grease, vegetable oils, and fish oils make up the other 40 percent (personal communication, Ray Rouse, 2000, Rouse Marketing, Cincinnati, OH).

As mentioned previously, fats and oils represent a highly concentrated source of energy. As a result, the voluntary intake of feed by pigs is less when fat is included in the diet. This fact, coupled with perhaps a slight increase in growth rate means that feed conversion efficiency (or feed-to-gain ratio) is markedly improved when fat is included in swine diets. On average, every one percent inclusion of fat reduces the amount of feed required per unit of gain by pigs by approximately two percent. This means less feed handling by the producer. Table 10 shows typical responses of growing-finishing pigs to added fat in diets. In some instances, carcass backfat may be increased slightly in pigs fed fat.

The addition of fat to feed improves the physical properties of the feed. When feed is pelleted, added fat makes the feed easier to pellet. It also reduces wear and tear on feed handling equipment. Also, one of the major advantages of using fat in feeds is that it greatly reduces feed dust in mills and buildings housing swine. Since microorganisms tend to travel on dust particles, reduced dust means fewer respiratory problems in pigs raised in confinement buildings as well as handlers who work in the buildings (Curtis et al., 1975). Studies have shown fewer lung lesions in pigs raised in confinement buildings in which the feed contains three to five percent fat (Gordon, 1963).

Fat additions to lactating sow diets have been shown to increase milk yield, increase the fat content of milk, and result in increased survival and weaning weights of pigs (Pettigrew, 1981).

Table 10. Effects of Supplemental Fat on Performance of Growing-Finishing Pigs.

	Study 1[a]		Study 2[b]	
	Added Fat, Percent			
Item	0	5	0	6
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Daily gain, lb	1.68	1.77	1.93	1.99
Daily feed intake, lb	5.44	5.22	5.31	5.03
Feed/gain	3.24	2.95	2.75	2.53
Carcass average backfat, in.	1.20	1.31	-	-
Carcass 10^{th} rib backfat, in.	-	-	0.74	0.76
Ham-loin percent	43.40	42.30	-	-

[a] Cromwell, 2002. Summary of five experiments, 88 pigs per treatment from 57 to 208 lb body weight. Research by the University of Kentucky and the University of Nebraska.
[b] Akey research, 2001. Courtesy of Ken Bryant, Akey Inc., Lewisburg, OH.

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