Protein and Amino Acids for Swine
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January 1977
6 pages

Fact Sheet 19.47.01
Extension Bulletin E-1066, Jan. 1977

pork industry handbook

COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

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No pig can develop lean tissue (muscle) to its genetic potential nor can a sow realize her maximum reproductive potential unless their diets contain sufficient protein with the correct amino acid composition. Protein is made up of many sub-units called amino acids. During the digestive process, proteins are broken down into individual amino acids. The animal absorbs amino acids from the intestines and recombines them within the body tissue into new protein molecules. Each of the body proteins are synthesized by the amino acids joining together in a pre-established sequence dictated by the genetic background of the animal.

Muscle protein is composed of about 22 different amino acids. Ten of these amino acids must be supplied in the pig's diet; the others can be synthesized in the body rapidly enough for maximum growth if a source of dietary nitrogen and adequate energy are present. The 10 that must be supplied in the diet are called *essential* amino acids; the others are classified *non-essential*. The 10 essential amino acids required by swine include: arginine, histidine, isoleucine, leucine, lysine, methionine + cystine, phenylalanine + tyrosine, threonine, tryptophan and valine.

Actually, swine do not have a protein requirement per se, but rather they have a dietary requirement for:

1. Non-specific nitrogen to synthesize the non-essential amino acids.
2. Specific amounts of the essential amino acids.

Any diet formulated from natural feedstuffs that satisfies the second requirement will automatically satisfy the need for non-specific nitrogen. Even though the pig does not have a specific protein requirement, most ration formulators have attempted to meet the amino acid requirements simply by feeding prescribed protein levels. Most rations will meet this objective *if* high quality protein feeds are used with the cereal grains.

Protein synthesis is an "all or nothing" type of synthesis. If any one of the essential amino acids needed to form a protein is deficient, that protein cannot be formed. Nothing explains the concept of limiting amino acids better than the age-old illustration that likens a protein to a wooden barrel made up of rings and staves. The amino acids are the staves, and since a barrel will only hold water to the height of its lowest stave, a protein will only allow the pig to lay down meat to the extent of the amino acid present in the least amount. This amino acid, the shortest stave in the protein barrel, is called the *first-limiting amino acid,* the next in shortest supply, the *second-limiting amino acid* and so on. Therefore, *quality of protein* (presence and amount of the 10 essential amino acids) is more important than the total amount of protein fed.

Several principles of protein-amino acid nutrition are illustrated in the results of a 21-day feeding trial conducted with young pigs averaging approximately 20 lb. initially. Two different high protein sources (soybean and peanut meal) plus supplemental lysine were used in the sorghum-based diets.

Diet				Pig performance		
No.	Type of diet	Dietary lysine	Dietary protein	Daily gain	Daily feed intake	Gain/feed
		percent		pound		
1.	Sorghum-soybean meal	1.07	20.2	1.19	2.28	.52
2.	Sorghum-peanut meal	.54	20.2	.55	1.54	.36
3.	As 2 + lysine	1.07	20.2	.92	2.23	.41
4.	Sorghum-peanut meal	1.07	40.0	.68	1.55	.44

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The control diet consisted of sorghum and soybean meal which was formulated to provide 1.07% lysine, which is 110% of the N.R.C. lysine recommendation for this weight pig. To obtain the level of lysine desired, enough soybean meal was added to give a 20.2% protein diet. When sorghum and peanut meal were used to achieve the same protein level (diet 2), lysine was severely deficient and the average daily gain and gain/feed were greatly reduced compared to those on diet 1. This was due to its *lower percentage of lysine* (the first-limiting amino acid) and less feed consumption as compared to diet 1. The low feed intake for diet 2 is attributed to the *lysine deficiency* and/or *amino acid imbalance.*

In the formulation of diet 3, supplemental lysine was added to the 20.2% peanut meal diet (diet 2) to give the same lysine level as in diet 1 (1.07%). Feed intake, daily gain and gain/feed were higher on diet 3 than on diet 2, which clearly demonstrates that lysine was the first limiting amino acid in diet 2. However, the average daily gain of pigs fed diet 3 was less than those supported by diet 1 (.92 vs 1.19 lb./day). This suggests that *other amino acids (in addition to lysine) are deficient* in diet 3 compared to diet 1.

In diet 4, the same dietary level of lysine as in diet 1 and 3 was achieved by adjusting the sorghum-peanut meal ratio. Gain performance, while better than that achieved by pigs fed diet 2, was much lower than for pigs fed diet 3 (.92 vs .68 lb./day). Therefore, feeding more of a lysine-deficient protein, such as peanut meal, is an inefficient means of meeting the dietary need for lysine. These results also suggest that the high percentage of peanut meal used in diet 4 resulted in an *amino acid imbalance.*

Other important concepts of protein-amino acid nutrition of swine that have been firmly established through controlled research include the following:

1. Amino acid requirements expressed as a percent of the diet are a function of:
   - Age, weight and function of animal
     - *Decrease with age and weight.*
     - *Higher for lactation than gestation.*
   - Protein content of diet
     - *Requirement for a specific amino acid increases as dietary protein level increases and decreases as dietary protein level decreases.*
   - Caloric density of diet
     - *Increases as energy level increases.*
   - Meatiness and sex
     - *Higher for more muscular animals.*
     - *Higher for gilts than barrows.*
   - Interrelationship among amino acids
     - *Cystine can furnish at least 50% of the requirement for total sulfur-bearing amino acids (methionine + cystine).*
     - *Tyrosine can provide about 30% of the phenylalanine requirement.*
     - *Methionine in excess can completely eliminate the dietary need for choline (B-vitamin); however, the reverse is not true, excessive choline does not lower the requirement for methionine.*
     - *Tryptophan can be converted to the essential B-vitamin, niacin, but the conversion is inefficient (e.g., 50 gm. tryptophan will yield only 1 gm. of niacin). The reverse reaction does not occur (niacin cannot be converted to tryptophan).*
     - *Excess lysine in the diet increases the requirement for arginine.*
     - *Excess leucine increases the requirements for valine and isoleucine.*
     - *Excess methionine increases the requirement for threonine.*
2. Regardless of sex, maximal carcass leanness requires a higher level of dietary amino acids than maximal rate of gain.
3. A diet with a good amino acid balance, even though it is below the traditional level in total protein and essential amino acids, has little or no depressing effect on voluntary feed intake. However, a deficiency of even one amino acid or an imbalance of amino acids (excess of one or more in relation to others) will cause a reduction in feed intake and daily gains.
4. Pigs utilize the L-isomers of all amino acids (L-isomers are present in natural feedstuffs) but only utilize the D-isomers of methionine and tryptophan effectively. D-methionine is equal to L-methionine; D-tryptophan has about 60% of the biological value of L-tryptophan.

These concepts provide guidelines that must be considered when attempting to generalize about the protein and amino acid needs of swine to optimize reproductive efficiency, feedlot performance, carcass merit and production costs.

Amino Acid Requirements

The requirements for the 10 essential amino acids during various stages of the growing-finishing period recommended by the National Research Council are given in Table 1. These reflect averages for published data that were found to be needed for normal health and performance of experimental animals. They do not include a safety factor; therefore, persons applying these standards may need to increase the levels of certain amino acids to meet specific conditions. Most of these requirements have been established using corn-soybean meal diets; hence they may need modification as other feed ingredients are used, especially as it relates to amino acid availability.

Please note that the amino acid requirements, expressed as a percent of the diet, decrease as a pig becomes heavier. Requirements are greatest during the rapidly growing stages of the young animal. Not only is the young animal growing at a more rapid rate (greater percentage increase in body weight per day) but also the proportion of protein in the weight gain is higher than during the finishing period. These changes in rate of growth and body composition are the basis for recommending different dietary protein levels to meet the amino acid requirements during the life of the pig.

Although the exact needs for some amino acids required for optimum reproduction are still in question, intensive research in the past decade has provided excellent guidelines for maintenance, gestation and lactation (Table 2). Illinois workers reported the maintenance requirements in 1966 and later provided evidence that the requirements during gestation could be divided into two periods (first 80 days of gestation, days 80-114 of gestation). It appears that a vitamin- and mineral-fortified corn or sorghum diet may be sufficient during early gestation, but it is inadequate during the last trimester of pregnancy when fetal growth is most rapid. Feeding the low level throughout gestation does not affect farrowing performance but will not support optimal lactation performance of the dam as shown by reduced litter weaning weights. This is the basis for listing the gestation requirements for the first two-thirds and for the last one-third of pregnancy.

The amino acid requirements for lactation are less well defined than those for gestation, but great progress has been made in the last few years. Illinois workers first estimated the essential amino acid requirements for the lactating sow in 1969. Since 1971, Iowa State workers have determined the lysine, total sulfur amino acids, threonine, tryptophan, leucine and isoleucine requirements for lactating sows. Using the Illinois estimates and calculations from their experiments, Iowa workers have suggested the requirements for the first, second and third reproductive cycles that are given in Table 2. Fortunately, the requirements for the amino acids that have been determined have agreed reasonably well with the calculated estimates. The daily quantitative requirements for individual amino acids have varied greatly because of the wide variation in milk production and milk composition. However, recent research suggests that the percent levels of lysine shown in Table 2 for lactating sows is usually adequate, provided that feed intake is proportional to her milk production potential.

The amino acid requirements for maintenance are less than during gestation, and gestation requirements are lower than for lactation (Table 2). Recent research has clearly demonstrated that swine have a remarkable capacity to buffer their offspring against a dietary protein or amino acid deficiency. It is apparent that pregnant and lactating swine can successfully carry out their intended functions of producing large, healthy pigs at weaning on substantially lower intakes of protein and amino acids than formerly thought possible.

Amino Acids in Grain

Although cereal grains are used primarily as sources of energy in a swine ration, they also contribute protein and amino acids to the diet. The essential amino acid composition of today's corn and sorghum hybrids are quite similar (Table 3). Compared to the young pig's (40 lb.) requirement, lysine is the first-limiting amino acid in both grains, although experiments with corn have revealed that tryptophan, perhaps due to a lower availability, is more limiting than lysine. For the 40-lb. pig, both grains contain adequate levels of arginine, histidine, leucine and phenylalanine + tyrosine, while both are deficient in tryptophan, threonine, sulfur-bearing amino acids and isoleucine.

Oats, wheat and barley are somewhat higher in protein than corn, but they contribute little more toward meeting the amino acid requirements of the growing pig since they are also deficient in lysine, threonine, isoleucine and the sulfur-amino acids. However, all of these grains contain more lysine than corn and sorghum. Hence, slightly less high quality protein supplement is required in formulating diets containing these grains. One practical way to allow for this slightly superior amino acid balance (when formulating diets on a percent protein basis) is to figure these grains at 11.0% protein as compared to 9% for corn and sorghum. Even though sorghum generally contains slightly more protein than corn, the same amount of protein supplement must be fed with sorghum as corn because the level of lysine is usually slightly lower for sorghum than corn (Table 3). Because of its relatively high level of crude fiber, oats should generally not comprise more than 25% of a swine diet.

Opaque-2 corn is richer in lysine and tryptophan than regular hybrid corn. Its protein level is similar to regular corn. Decisions concerning when to use *opaque-2* corn in swine rations should be made on the basis of economics, yield characteristics and lysine content of the particular varieties available. Several recent studies have shown that commercially available *opaque-2* corn contains between 30 and 50% more lysine and tryptophan than regular corn.

Amino Acids in High Protein Feedstuffs

Since lysine, tryptophan, threonine, isoleucine and the sulfur-bearing amino acids are the most deficient in corn and sorghum, high protein feedstuffs should be evaluated primarily on their ability to correct these deficiencies, *particularly that of lysine.* Table 4 gives the lysine, tryptophan, threonine, isoleucine and methionine + cystine values in several high protein feeds. Since high protein feedstuffs vary so widely in percentage of protein (85% for feather meal, 12% for dried whole whey) the *amino acid content expressed as a percent of protein* is a more accurate yardstick to use in evaluating the ability of a protein source to correct the amino acid deficiencies of grain than the percentage of amino acid in the feedstuff. In formulating a 16% grower diet from corn or sorghum using a 38% protein supplement, the supplement must contain *(as a percent of the protein)* the minimum or higher amounts of the following amino acids: lysine, 6.25%; tryptophan, .66%; threonine, 2.41%; isoleucine, 2.74%; methionine + cystine, 2.74%.

The values given in Table 4 show that only fishmeal and dry buttermilk satisfy all the requirements. Dried whole whey and soybean meal appear to be marginal in the sulfur-bearing amino acids. However, methionine additions to corn-soybean meal or sorghum-soybean meal diets have failed to improve performance. Hence, fish meal, dry buttermilk, whole dried whey or soybean meal would appear to provide an amino acid balance that complements and corrects the deficiencies of corn and sorghum. Of these, however, soybean meal is the only protein source that results in optimal performance when combined with grain. The available tryptophan content of fish meal may be its limiting factor, while the lactose content of dried whey and buttermilk would limit its use, especially for pigs beyond 8 weeks of age. Moreover, the supply and price of fish meal and the milk products prevent their routine use in swine feeds.

Tankage (meat meal) contains sufficient lysine, but tryptophan and the sulfur amino acids are marginal. Meat and bone meal is limiting in both tryptophan and lysine. Meat products such as these are high in ash and therefore less palatable. They should not comprise more than 3-5% of the complete ration.

Several of the high protein feeds in Table 4 are lysine-deficient including cottonseed meal, peanut meal, feather meal, corn gluten and sorghum gluten meals. Cottonseed and peanut meals can be used effectively to provide a portion of the protein supplement, but they must be fed in combination with other high protein feedstuffs that have a high lysine content to obtain maximum performance.

At current prices, soybean meal is the high protein feed of choice to correct the amino acid deficiencies of grain.

Use of Synthetic Amino Acids

The protein shortage of 1972-73 stimulated research and practical demonstrations that more adequately defined the role that synthetic lysine can play in swine feeding. Unfortunately, lysine and methionine are the only two essential amino acids available today in the feed-grade form. However, there are indications that feed-grade tryptophan and threonine will be commercially available in the next few years.

Although the world's annual production is limited, feed-grade lysine has been used in swine feeds for several years. Its price in relation to the cost of lysine in high protein feedstuffs has limited its use except when high protein feeds are unusually expensive. However, research has clearly demonstrated that supplemental lysine can significantly reduce the amount of high quality soybean meal needed in swine diets. Theoretically, ration formulators only need to add enough soybean meal to meet the requirement for the second-limiting amino acid, then add enough synthetic lysine to meet the lysine requirement. Feedlot performance on the lower-protein

Table 1. Amino acid requirements for growing-finishing swine at various weights*

Amino acids	Pig weight, lb.				
	10-22	22-44	44-77	77-132	132-220
	percent of diet				
Arginine	.28	.23	.20	.18	.16
Histidine	.25	.20	.18	.16	.15
Isoleucine	.69	.56	.50	.44	.41
Leucine	.83	.68	.60	.52	.48
Lysine	.96	.79	.70	.61	.57
Methionine + cystine†	.60	.55	.50	.40	.30
Phenylalanine + tyrosine‡	.69	.56	.50	.44	.41
Threonine	.62	.51	.45	.39	.37
Tryptophan	.18	.15	.13	.11	.11
Valine	.69	.56	.50	.44	.41

*N.R.C. 1973. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Swine. National Research Council, Washington, D.C. Methionine + cystine requirements have been adjusted to reflect information published after 1973.

† Methionine can fulfill the total requirement; cystine can supply at least 50% of the total requirement.

‡ Phenylalanine can fulfill the total requirement; tyrosine can fulfill 30% of the total requirement.

Table 2. Amino acid requirement (percent of diet) of adult female swine.

Item	Mainte-nance*	Gestation*		Lactation†		
		Days 0-80	Days 81-114	Gilt	2nd litter	3rd litter or more
Feed intake, lb./day	4	4	4	9	10	12
Crude protein	3.0	9.0	12.0	14.0	14.0	14.0
Amino acids						
Arginine	0	---	---	.39	.43	.41
Histidine	0	.10	.17	.22	.24	.23
Isoleucine	.07	.22	.37	.34	.37	.35
Leucine	.04	.33	.56	.65	.71	.68
Lysine	.06	.25	.42	.59	.64	.61
Methionine + cystine	.06	.17	.28	.26	.28	.27
Phenylalanine + tyrosine	.05	.18	.30	.67	.73	.71
Threonine	.09	.20	.34	.36	.38	.37
Tryptophan	.01	.04	.07	.10	.11	.11
Valine	.05	.27	.46	.41	.44	.43

*Baker, D. H., and coworkers, University of Illinois.
† Speer, V. C., and coworkers, Iowa State University.

Table 3. Essential amino acid content of commonly used swine feeds.*

	Protein	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Cystine	Phenylalanine	Tyrosine	Threonine	Tryptophan	Valine
	percent												
Grains													
Corn†	8.8	.42	.24	.31	.98	.26	.19	.20	.41	.35	.32	.09	.46
Sorghum‡	9.0	.36	.21	.38	1.13	.22	.17	.14	.46	.37	.29	.09	.70
Barley§	11.7	.58	.27	.54	.81	.36	.18	.19	.63	.36	.36	.16	.63
Corn, high lysine#	8.5	.53	.28	.27	.70	.37	.16	.18	.35	.27	.31	--------	.41
Oats§	12.0	.58	.15	.39	.66	.34	.18	.15	.39	.60	.33	.13	.46
Wheat§	12.2	.60	.28	.46	.88	.38	.20	.16	.62	.38	.37	.15	.55
Protein Sources§													
Soybean meal	44	3.20	1.21	2.32	3.62	2.88	.56	.66	2.35	1.46	1.87	.55	2.31
Soybean meal	50	3.54	1.30	2.49	3.88	3.14	.73	.82	2.52	1.56	2.00	.63	2.48
Alfalfa meal, dehydrated	17	.94	.29	.72	1.09	.80	.29	.29	.72	.43	.58	.36	.80
Blood meal	80	3.20	3.79	.88	9.89	5.37	1.04	1.40	5.17	1.78	3.87	1.02	6.91
Buttermilk, dry	32	1.08	.80	2.17	3.13	2.20	.72	.41	1.43	1.01	1.46	.47	2.40
Cottonseed meal, solvent	41	4.27	1.00	1.18	2.12	1.55	.49	.65	1.96	1.03	1.19	.48	1.60
Distillers dried solubles (corn)	27	1.03	.70	1.72	2.21	.77	.50	.36	1.72	.61	1.01	.18	1.61
Fish meal (menhaden)	60	4.06	1.55	2.99	4.79	4.60	1.88	.62	2.65	2.14	2.67	.71	3.42
Meat & bone meal	50	3.59	.90	1.71	3.12	2.50	.65	.62	1.81	.84	1.81	.29	2.42
Peanut meal, expeller	50	5.23	.94	1.47	2.62	1.35	.54	.34	2.17	1.72	1.13	.48	2.72
Tankage (meat meal)	60	3.69	1.95	1.95	5.26	3.89	.75	.52	2.78	.96	2.48	.58	4.32
Wheat bran	15	.95	.29	.56	.85	.56	.09	.29	.47	.38	.38	.29	.66
Wheat midds, standard	16	.83	.37	.73	1.10	.64	.16	.18	.63	.37	.54	.18	.73
Whey, dried whole	12	.27	.16	.72	1.00	.80	.16	.24	.28	.16	1.03	.13	.56
Yeast, brewers dried	45	2.22	1.11	2.12	3.23	3.02	.71	.50	1.82	1.52	2.12	.50	2.31

*All values on a 90% dry matter basis.

† Average for over 80 hybrids grown in Illinois, Virginia and Texas 1972-75.

‡ Average for 15 hybrids grown in Texas 1973-75.

§ Most values were obtained from "Atlas of Nutritional Data on United States and Canadian Feeds," National Academy of Sciences (1971), and adjusted to the indicated protein level.

Average for 56 commercially grown opaque-2 corns in Virginia 1973-74 with adjusted cystine value.

Table 4. Lysine, tryptophan, threonine, isoleucine and sulfur amino acid content of selected high protein feeds.*

		Lysine		Tryptophan		Threonine		Isoleucine		Methionine + cystine†	
	Protein	Feed	Protein	Feed	Protein	Feed	Protein	Feed	Protein	Feed	Protein
	percent										
Fish meal, menhaden	60	4.60	7.67	.71	1.18	2.67	4.45	2.99	4.98	2.50	4.17
Buttermilk, dry	32	2.20	6.88	.47	1.47	1.46	4.56	2.17	6.78	1.12	3.50
Whey, dried whole	12	.80	6.66	.13	1.11	1.03	8.58	.72	6.00	.32	2.67
Soybean meal, solvent	44	2.88	6.55	.55	1.25	1.87	4.25	2.32	5.27	1.13	2.57
Tankage (meat meal)	60	3.89	6.48	.58	.97	2.48	4.13	1.95	3.25	1.27	2.12
Meat and bone meal	50	2.50	5.00	.29	.58	1.81	3.62	1.71	3.42	1.27	2.54
Cottonseed meal, solvent	41	1.55	3.79	.48	1.17	1.19	2.90	1.18	2.88	.96	2.34
Peanut meal, expeller	50	1.39	2.79	.48	.96	1.13	2.26	1.47	2.94	.87	1.74
Feather meal, hydrolyzed	85	1.94	2.28	.49	.58	3.75	4.41	3.59	4.22	1.19	1.40
Corn gluten meal	42	.80	1.92	.23	.55	1.51	3.60	2.49	5.93	1.77	4.21
Sorghum gluten meal	42	.68	1.62	.39	.93	1.38	3.28	2.23	5.31	1.17	2.79

*90% dry matter basis.

† Effective total sulfur amino acid value. If cystine content was higher than methionine value, it was reduced to the methionine value since cystine can provide only 50% of the total requirement for sulfur-bearing amino acids.

lysine-supplemented diets has been good. The best current estimates for the dietary protein and lysine requirements for conventional and the lower-protein lysine supplemented diets for different weights of growing-finishing pigs are shown below:

Period	Dietary protein	Lysine requirement (percent of diet)
Starter	19	.96
10-40 lb.	16*	.90
Grower	16	.77
40-100 lb.	14*	.73
Finisher I	14	.60
100-160 lb.	12*	.56
Finisher II	13	.50
160-220 lb.	11*	.46

*Supplemental lysine would be necessary to achieve the lysine requirement at this level of protein in corn-soybean meal diets. For sorghum-soybean meal finisher diets I and II, protein levels should be increased by 1% for equal performance.

Two separate requirements are listed for starting, growing and finishing swine. These are based on the well-documented premise that the requirement for lysine, expressed as a percentage of the diet, decreases with each reduction in dietary protein level. Therefore, when soybean meal is replaced in the diet by grain plus synthetic lysine so that the total dietary protein level is lowered by about 2%, the necessary *total concentration* of dietary lysine is reduced. Recent work at the Illinois station indicates that the lysine requirement seems to decrease by .02% of diet for each 1% decrease in the level of dietary protein.

When you use synthetic lysine, you are replacing some of the soybean meal in each ton of feed with a combination of grain (corn or sorghum) and synthetic lysine. As a thumb rule, 3 lb. feed-grade lysine monohydrochloride (78.4% L-lysine) and 97 lb. grain can replace 100 lb. 44% soybean meal per ton of ration. In cost, it is advantageous to use synthetic lysine when 3 lb. lysine monohydrochloride and 97 lb. grain can be purchased for less than 100 lb. soybean meal. However, in actual practice, the cost difference needs to be fairly wide to justify changing ration mixing procedures.

Undoubtedly, as the world demand for soybean meal for human food becomes greater, the use of supplemental amino acids will become increasingly important. The extent of their use in the years ahead will depend primarily on:

1. Availability and price of feed-grade amino acids.
2. Increased understanding of amino acid requirements with emphasis on amino acid availability and amino acid balance.