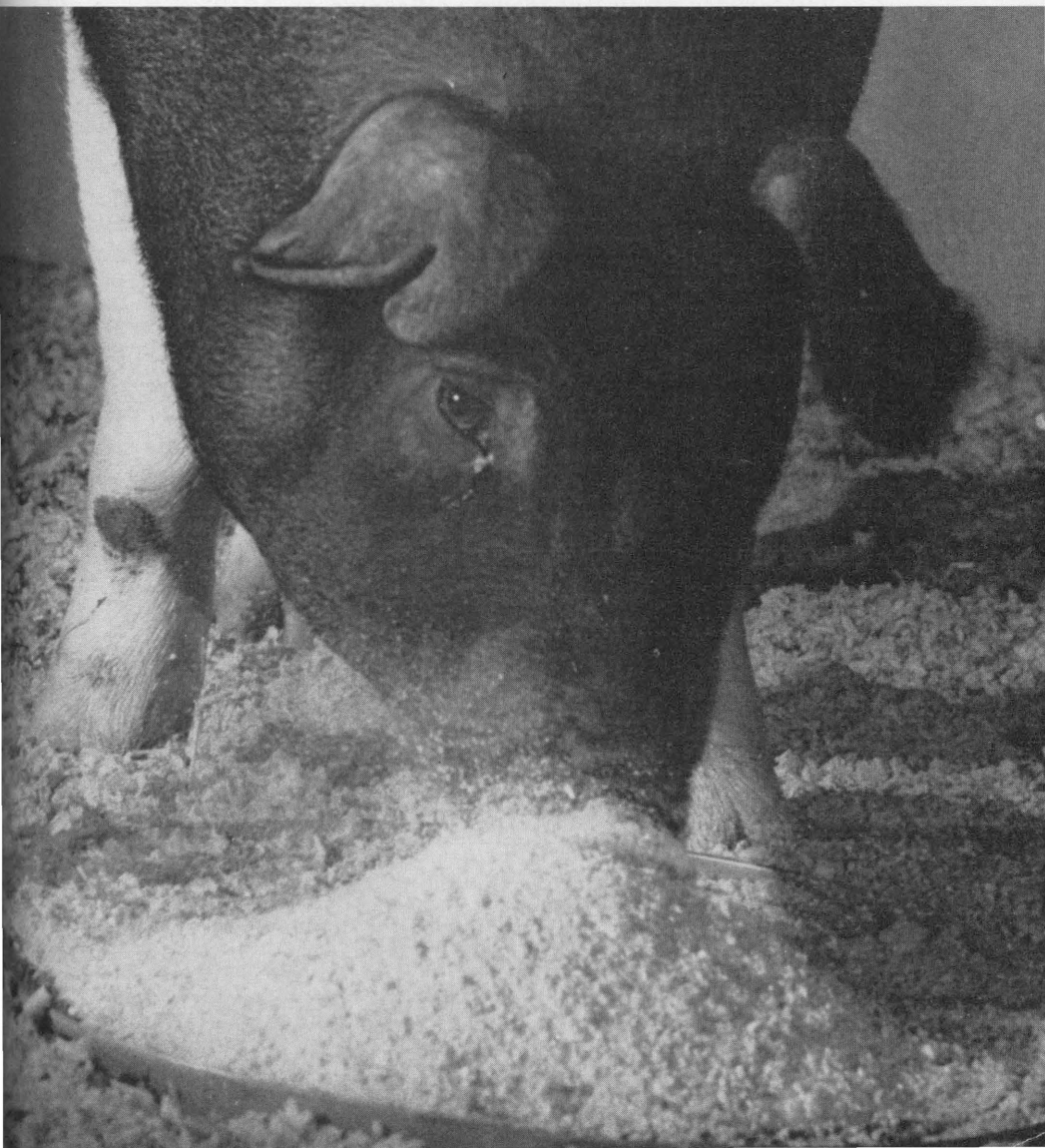
BALANCING SWINE RATIONS

The Illinois System of Swine Nutrition

By D. E. Becker, A. H. Jensen, and B. G. Harmon

CIRCULAR 866 · UNIVERSITY OF ILLINOIS COLLEGE OF AGRICULTURE COOPERATIVE EXTENSION SERVICE



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Like any other business, the swine operation must be managed with maximum efficiency to be profitable. Since feed costs make up 75 percent of the total cost of producing pork on Illinois farms, a skillfully formulated feeding program is essential for efficient swine production. To develop rations that are nutritionally adequate as well as economical, the swine producer needs a thorough knowledge of the nutrient requirements of swine. The first part of this circular discusses the nutrient balance of various swine rations; the last part presents a modern system of swine nutrition developed at the University of Illinois.

In the past we recommended that growing and finishing hogs be self-fed an all-purpose supplement with shelled corn on good legume pasture. This system worked because the pig has a reasonable ability to balance his diet when fed on a free-choice basis, and because pasture consumption frequently overcame the nutrient deficiencies of the rations then in use. Better results are possible today, however, because we have learned that the pig has shortcomings in his ability to balance his diet when fed free-choice. In addition, our knowledge of the nutrient needs of swine is far more nearly complete, and it is no longer necessary to rely upon pasture as a source of vitamins and minerals.

The Illinois System of Swine Nutrition has been developed as a result of this recent experimental work on the practical nutrition of swine. This system is based largely on complete rations that make maximum use of soybean meal as the supplementary source of amino acids. Corn and soybean meal, formulated to provide 16- and 12-percent protein rations, and supplemented with the necessary vitamins, minerals, and antibiotics, constitute most of the feeding program.

BALANCING THE NUTRIENTS IN SWINE RATIONS

Balancing the nutrient content of swine rations is largely a matter of correcting the deficiencies of the cereal grain that serves as the primary source of energy. Yellow corn is the main cereal used in the Midwest, although it has several nutrient deficiencies for swine feeding. Corn contains only 7 to 9 percent protein, and this protein is deficient in practically all of the amino acids required by the weanling pig. Corn also lacks several vitamins and minerals. In formulating swine rations, it is important to consider these deficiencies carefully.

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Energy Feeds for Swine

Swine rations are usually developed around feeds used to supply calories or energy. Energy is the most costly ingredient of swine rations. For example, yellow corn, an energy feed that makes up about 80 percent of the average swine ration, accounts for about 65 to 70 percent of the total cost of the ration. Yellow corn is usually the cheapest source of energy, but price fluctuations frequently justify consideration of other feeds.

The relative values of various feeds that may be used as complete or partial replacements of yellow corn in grower, finisher, or breeder rations are shown in Table 1.

Table 1. — Value of Corn Substitutes in Grower, Finisher, and Breeder Rations

Feed	Relative value (percent)	Pounds equal to 1 pound of yellow corn
Yellow corn, ground	100	1.00
Complete substitutes:		
Oats, rolled or dehulled	107	.93
Wheat, ground	95	1.05
Barley, ground	86	1.16
Sorghum (milo), ground	94	1.06
Partial substitutes: maximum recommended replacement of corn		
Oats, ground—25 percent	82	1.22
Rye, ground—20 percent	90	1.11
Blackstrap molasses—5 percent	59	1.69
Dried whey—5 percent	90	1.11
Tallow—5 percent	241	.41
Lard—5 percent	232	.43

Preparation of energy feeds

Grinding is the most feasible method of feed preparation for use by the swine producer. For grains that are likely to be incompletely digested, grinding frequently yields benefits that more than justify the cost of grinding. In fact, the evidence suggests that all of the commonly used grains should be ground for best utilization. Furthermore, any feeding method (such as limited feeding) that stimulates a rapid consumption of the ration will usually increase the advantage of grinding. The benefit of grinding is usually greater for the older pig.

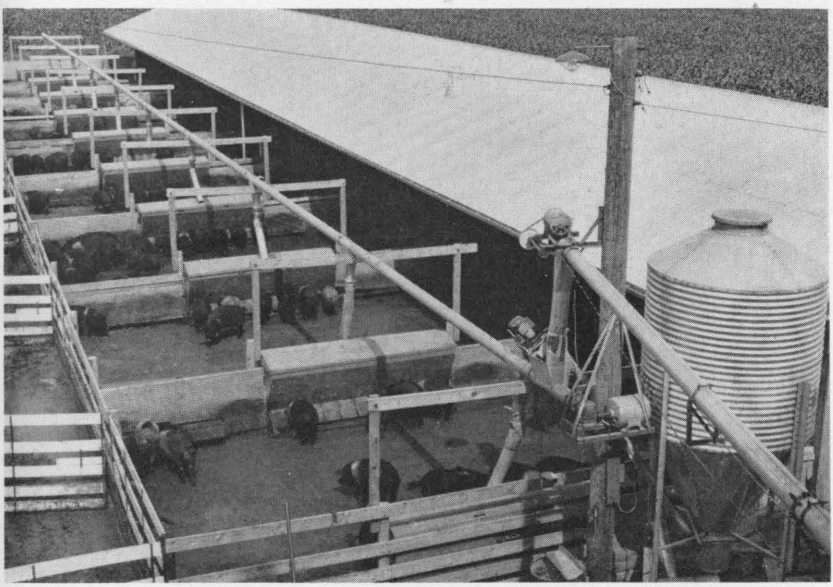
Crushing, grinding, or rolling appear to be equally effective when the process has prepared the grain to the same degree of fineness.

The recommended fineness for grinding various grains is indicated below.

Grain	Relative Fineness
Barley	Medium
Corn	Medium
Sorghum (milo)	Coarse
Oats	Medium fine
Rye	Coarse
Wheat	Coarse

Pelleting of complete rations that contain corn as the primary source of energy has not improved the rate and efficiency of gains by growing-finishing pigs. On the other hand, rations that contain large amounts of barley, alfalfa meal, or other fibrous feeds frequently show a pronounced advantage when pelleted. The cost of the process, however, makes it difficult to justify the pelleting of complete rations for growing-finishing pigs. With creep feeds, in which a choice of commercial feeds is possible, it is felt that the pelleted form may be more palatable. Likewise, pelleted supplements may be desirable to minimize wastage caused by wind.

There is still no evidence that cooking, soaking, fermenting, or liquid feeding of the ration is of value when swine are full-fed.

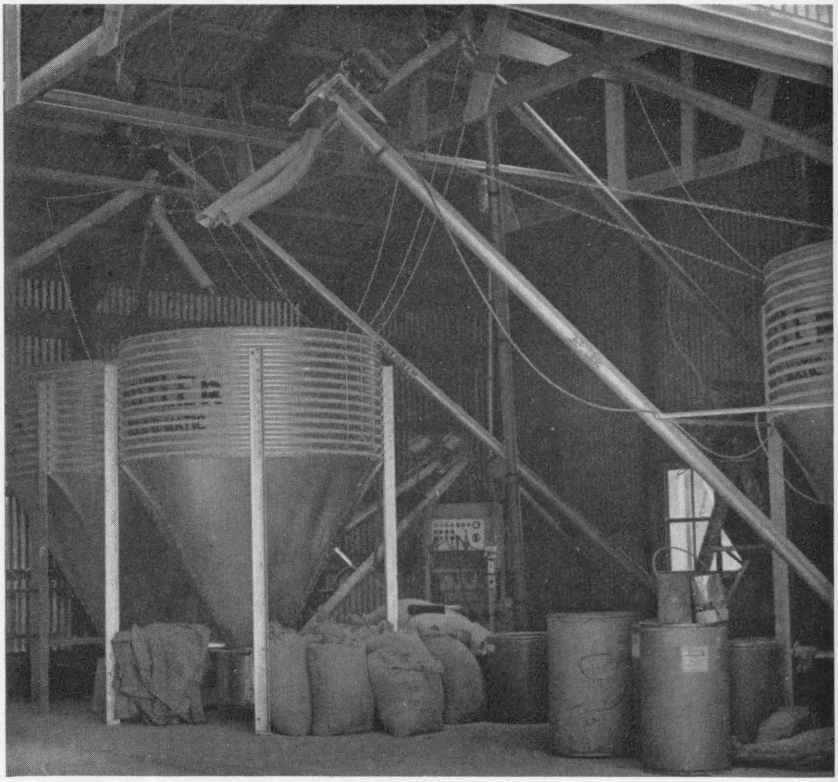


A modern facility for feeding growing and finishing pigs in drylot.

The minimum protein levels needed for optimum performance have received considerable attention. Recommended protein feeding levels are listed in Table 2.

Recommended Protein Levels

Perhaps no class of nutrients is more critical in swine rations than proteins or their components, amino acids. Protein is needed in the diet of all classes of swine to supply amino acids for the physiological processes — maintenance, growth, reproduction, and lactation. For instance, a deficiency of protein or of any one of the essential amino acids in the diet of a growing pig results in slowed or arrested growth, depressed appetite, and inefficient feed utilization. Since 40 to 60 percent of the pig's total dietary protein is supplied by the low-quality protein of corn, the addition of supplementary protein or amino acids is very important.



A modern facility for mixing swine rations on the farm.

Table 2. — Recommended Protein Levels, Average Rate of Gain, and Feed Intake Values for Swine

Classification	Protein content of ration (percent)	Average daily gain (pounds)	Average daily feed intake (pounds)
Growing and finishing pigs			
Creep feed (suckling)—5 to 30 pounds	20	0.70	0.50
Pig starter (weaned)—10 to 30 pounds	22	0.65	1.10 (1.65)[a]
Grower—30 to 100 pounds	16	1.40	3.65 (2.60)[a]
Finisher—100 to 200 pounds			
Full-fed	12	1.90	6.85 (3.60)[a]
70 percent of full-fed or 5 pounds per head daily	12	1.50	5.00 (3.30)[a]
4 pounds per head daily	12	1.35	4.00 (3.00)[a]
Gestation			
Gilts—first ⅔	16	0.60	4.00
last ⅓	16		5.00
Sows—first ⅔	12	0.50	4.00
last ⅓	16		5.00
Lactation			
Gilts and sows	16	....	12.00
Breeding boars	16	....	6.00

[a] Figure in parentheses indicates average feed required per pound of gain.

Excessive protein intake

Despite reports of protein poisoning, it is unlikely that excessive protein intake causes illness or death in swine. At the Illinois Station, a 42-percent protein diet composed of soybean meal, alfalfa meal, meat and bone scrap, minerals, and antibiotic failed to produce death losses in growing and finishing swine. Although the rate of gain was depressed and diarrhea was prevalent, there was no other evidence of disease or toxic effects.

Inadequacy of protein feeding standards

Proteins are the source of dietary amino acids, and swine nutritionists have attempted to comply with minimum amino acid requirements by adhering to prescribed protein levels. According to Table 2, for example, the 30-pound growing pig should be fed a ration containing 16 percent protein. The implication here is that all such rations would contain adequate amounts of the amino acids. The data presented in Table 3, however, demonstrate that diets containing 18 percent protein may be inadequate for proper amino acid nutrition of the weanling pig.

Table 3. — Experiments Comparing 18-Percent Protein Rations for the 25-pound Pig, Illinois, 1959

	Number of pigs	Average daily gain (pounds)	Feed per pound of gain (pounds)
Experiment 1 (average pig weight, 41 pounds)			
Corn-soybean meal diet	8	1.04	3.06
Corn-fishmeal diet	8	.74	3.90
Corn-fishmeal diet+0.05 percent DL-tryptophan	8	1.16	3.44
Experiment 2 (average pig weight, 36 pounds)			
Corn-soybean meal diet	8	1.23	2.99
Corn-meat and bone scrap diet	8	.96	4.17
Corn-meat and bone scrap diet+0.1 percent DL-tryptophan	9	1.24	3.33

Weanling pigs fed 18 percent protein as either a corn-fishmeal diet supplemented with minerals and vitamins (Experiment 1) or as a diet of corn and meat scrap with minerals and vitamins (Experiment 2) failed to exhibit a satisfactory rate and efficiency of gain. The addition of tryptophan improved the rate and efficiency of gain in both experiments. This fact indicates that amino acid deficiencies can exist in the presence of protein levels that conform to the minimum recommendations.

As the basic ingredient of swine rations, corn supplies a considerable portion of the amino acids, although it is deficient in all of the essential amino acids except arginine and leucine. Histidine, valine, and phenylalanine, which are only slightly deficient in corn, are ordinarily supplied in plentiful amounts by the supplementary proteins. The levels of isoleucine, lysine, methionine, threonine, and tryptophan may be inadequate and need to be considered carefully.

Menhaden fishmeal and meat and bone scrap do not contain enough tryptophan to supplement corn adequately. Other sources of supplementary protein are also too deficient in certain amino acids to correct the deficiencies in corn protein. Tankage is lacking in tryptophan. Blood flour or meal is markedly deficient in isoleucine and slightly deficient in methionine. Cottonseed meal, linseed meal, and sesame meal contain limiting amounts of lysine.

In view of these facts, it is well to remember that protein feeding standards for swine merely express a quantitative need for protein. Protein, regardless of its amino acid distribution, will not necessarily satisfy the pig's need, even when fed at the prescribed level. For this reason, swine nutritionists must have a complete knowledge of amino acid needs when formulating diets.

Amino Acid Requirements

We have realized for a long time that it is the constituents of protein rather than protein itself that are critical in swine nutrition. Actually, *swine do not require protein in the diet.* Workers at the Purdue Station have obtained normal growth in weanling pigs fed only purified amino acids and an additional source of nitrogen.

Although about 22 amino acids have been recognized in animal feeds, only 10 of these are considered essential for swine nutrition. An essential amino acid is one that the pig cannot manufacture at a sufficiently rapid rate to permit maximum rate of gain. If a source of nitrogen is present, the non-essential amino acids can be synthesized by the body tissues, and therefore are not required in the diet.

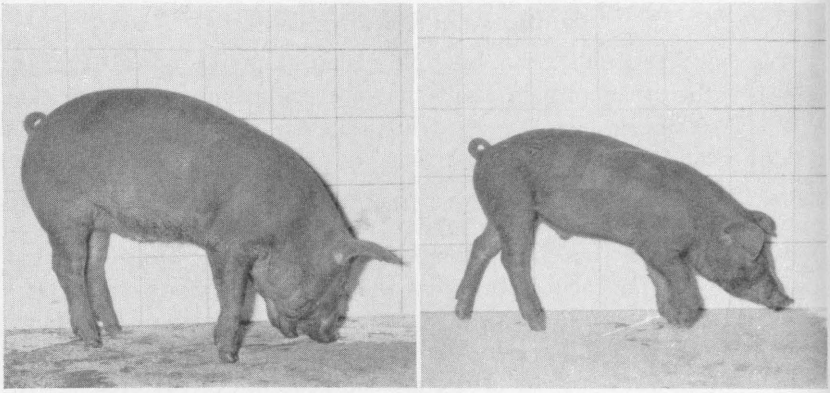
Although the non-essential amino acids are not required in the diet, cystine and tyrosine can satisfy a part of the need for the essential amino acids methionine and phenylalanine, respectively. The essential and non-essential amino acids for the pig are listed below.

Essential	*Non-essential*
Arginine	Alanine
Histidine	Aspartic Acid
Isoleucine	Citrulline
Leucine	Cystine
Lysine	Glutamic Acid
Methionine	Glycine
Phenylalanine	Hydroxyglutamic Acid
Threonine	Hydroxyproline
Tryptophan	Norleucine
Valine	Proline
	Serine
	Tyrosine

Until recently, it was assumed that the amino acid needs of swine were constant percentages of the dietary protein. But it is now clear, even though the individual amino acids have been studied at a very limited number of protein levels, that amino acid needs at one protein level will not necessarily satisfy the needs at all levels of adequate protein intake.

Most of the feeding trials for directly measuring the amino acid requirements of swine have been conducted at the Cornell, Illinois, and Purdue Stations. Studies at Illinois have shown that the isoleucine and lysine requirements expressed as a percent of the protein are not the same at two levels of adequate protein intake. In fact, the amounts of isoleucine and lysine required in the protein decrease as the level of protein increases.

A substantial amount of data with the chick seems to verify the



Essential Amino Acid Deficiency. The weanling pig on the left was fed a ration with adequate isoleucine. The pig on the right was fed an isoleucine-deficient diet for 28 days. Note the marked difference in growth.

conclusion that the required percentage of certain indispensable amino acids in the protein decreases rather directly as the protein level increases. It has not yet been determined, either for the pig or the chick, whether this interaction applies to all of the essential amino acids, but it seems logical to assume that it does.

The values for the weanling pig shown in Table 4 are based upon

Table 4. — Amino Acid Needs of the Pig at Various Stages of Development

Amino acid	Baby pig (10 pounds)	Weanling pig (30 pounds)			Finishing pig (100 pounds)
Level of dietary protein (%)[a]	22	14	16	18	12
		(percent of diet)			
Arginine	0.37	0.23	0.25	0.28	0.15
Histidine	0.34	0.21	0.23	0.24	0.14
Isoleucine	0.76	0.48	0.52	0.57	0.35
Leucine	0.98	0.63	0.67	0.74	0.40
Lysine	1.20	0.68	0.74	0.79	0.50
Methionine[b]	0.73	0.45	0.50	0.53	0.30
Phenylalanine[b]	0.79	0.49	0.54	0.58	0.32
Threonine	0.66	0.42	0.45	0.49	0.27
Tryptophan	0.18	0.11	0.12	0.13	0.07
Valine	0.67	0.43	0.46	0.50	0.28

[a] Calculations are based upon the assumption that the requirement for all amino acids, expressed as a percentage of the protein, decreases linearly as the dietary protein increases. The rate of the decrease is the mean of that reported for isoleucine and lysine. The need for each amino acid, expressed as a percent of the protein, was assumed to decrease 1.75 percent (from its value at 0 percent protein) per unit increase in percent protein.

[b] Cystine can satisfy 40 percent of the total need for methionine, and tyrosine can satisfy 30 percent of the total need for phenylalanine.

the principle that the amino acid requirements, expressed as a percent of the protein, decrease in a linear manner as the level of dietary protein increases. Our present knowledge of the amino acid needs of swine is limited to growing and finishing pigs; the requirement of breeding animals has not yet been defined.

Formulation of grower supplements on amino acid basis

Since drylot supplements are formulated to contain about 36 percent protein, pigs selecting a 16-percent protein diet will consume a combination of approximately 74 percent corn and 26 percent supplement (in 100 pounds of ration, corn will contribute about 6½ pounds of protein, and the supplement, about 9½ pounds). The weanling pig may consume an even higher level of protein, but the calculations shown here insure that he will get enough protein.

Minimum percentages of the various amino acids required in a 36-percent protein supplement are listed in Table 5. Since yellow corn consumed as 74 percent of the diet would fully satisfy the pig's requirement of arginine and leucine, these amino acids would not be needed in the supplement. The amounts of histidine, valine, and phenylalanine provided in the supplement are relatively unimportant — less than 30 percent of the total requirement. On the other hand,

Table 5. — Minimum Amino Acid Levels Required in a 36-Percent Protein Supplement

(For weanling pigs fed a 16-percent protein diet based on 74 pounds of corn to 26 pounds of supplement)

Amino acid	Total requirement	In 74 pounds of corn	In 26 pounds of supplement	Minimum level required in supplement
	(percent of diet)	(pounds)		(percent of supplement)
Arginine	.25	.28	...	...
Histidine	.23	.16	.07	.27
Isoleucine	.52	.26	.26	1.00
Leucine	.67	.78	...	...
Lysine	.74	.18	.56	2.15
Methionine	.30	.14	.16	.62
Cystine[a]	.20	.10	.10	.38
Threonine	.45	.23	.22	.85
Tryptophan	.12	.04	.08	.31
Valine	.46	.33	.13	.50
Phenylalanine	.38	.30	.08	.31
Tyrosine[a]	.16	.33	...	...

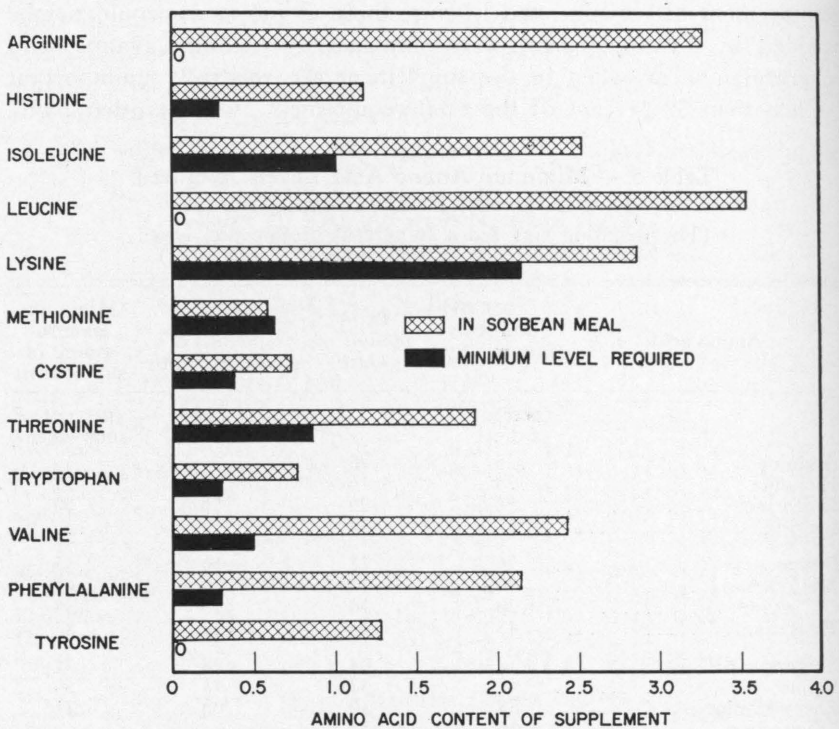
[a] Cystine can satisfy 40 percent of the total need for methionine and tyrosine can satisfy 30 percent of the total need for phenylalanine.

the supplement plays an important role in providing adequate levels of the remaining amino acids. Lysine, tryptophan, isoleucine, methionine, and threonine must be present in the supplement in sufficient concentration to supply 76, 67, 50, 53, and 49 percent of the total need, respectively.

Lysine and tryptophan are the primary amino acids required in the protein supplement. Usually sufficient isoleucine and threonine are provided if the requirement for lysine and tryptophan is satisfied with the supplementary proteins. If the supplementary protein is supplied largely as soybean meal, then the level of methionine in the supplement may be borderline.

Choice of amino acid supplements in grower and finisher rations

Soybean meal is an outstanding source of supplementary amino acids for feeding swine, and will satisfy the required amino acids for a supplement fed with corn (see chart below). Although soybean meal



The above chart shows that soybean meal completely satisfies the amino acid requirements in a supplement fed with corn.

contains only marginal amounts of methionine, recent studies have failed to demonstrate that a fortified 16-percent protein ration consisting of yellow corn and soybean meal is improved by supplementary methionine. The excellent amino acid distribution and low cost of soybean meal have made it the most popular source of supplementary amino acids in swine rations.

Of course, other supplements of varying amino acid distribution are available, and may be used as price differentials indicate. The economy of these supplements, however, must finally be determined on the basis of their ability to provide the essential supplementary amino acids rather than protein.

Calculated soybean meal replacement values for various amino acid supplements are shown in Table 6. In general, the ratings reflect the value of the various feeds in replacing up to 50 percent of the soybean meal in a fortified corn-soybean meal ration containing 16 percent protein. All of the feeds contain as much or more methionine than soybean meal, and tryptophan is not likely to be deficient when the ration contains at least 10 percent of soybean meal. Therefore, the replacement values of the supplements are calculated on their ability to provide lysine; the values are corrected for the variation in quantities required to replace soybean meal.

Quantitative Vitamin and Mineral Levels in Swine Rations

Recommended levels for those vitamins and minerals that demand serious consideration when formulating practical swine rations are

Table 6. — Value of Amino Acid Supplements in Grower and Finisher Rations

Supplement	Relative value (percent)	Pounds equal to 1 pound of soybean meal[a]
Soybean meal (44 percent protein)	100	1.00
Soybean meal (50 percent protein)	104	.96
Cottonseed meal	86	1.16
Linseed meal	81	1.23
Sesame meal	82	1.22
Distillers' solubles, dried	77	1.30
Fishmeal, menhaden	118	.85
Meat and bone scrap (50 percent protein)	101	.99
Tankage (60 percent protein)	110	.91
Blood meal	123	.81
Skimmilk, dried	96	1.04

[a] Values based upon the relative amount of supplements required in a 16-percent protein ration containing 50 percent of the recommended level of 44-percent soybean meal.

shown in Table 7. This table is not intended as a complete description of the needs for these two classes of nutrients. For example, with rations containing 80 percent yellow corn, a deficiency of vitamin E, vitamin K, thiamine, pyridoxine, folic acid, or biotin is unlikely. Similarly, it is not likely that magnesium, potassium, and sulfur will be deficient in usual swine rations, and cobalt does not seem to be required in rations amply fortified with vitamin B_{12}.

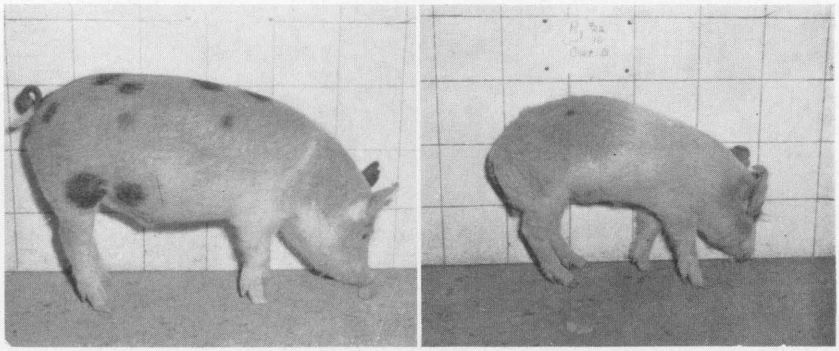
Table 7. — Recommended Vitamin and Mineral Levels for Swine Rations

Nutrient	Creep and starter rations	Grower ration	Finisher ration	Breeder ration
Fat-soluble vitamins				
Vitamin A, I.U. per lb.	1,500	1,750	1,950	2,500
or carotene, mg. per lb.	3.0	3.5	3.9	5.0
Vitamin D, I.U. per lb.	300	150	75	150
Water-soluble vitamins				
Riboflavin, mg. per lb.	1.50	1.00	.80	1.00
Nicotinic acid, mg. per lb.	12	8	6	8
Pantothenic acid, mg. per lb.	7.5	5.5	5.0	5.5
Choline, mg. per lb.	600	400	350	370
Vitamin B_{12}, mcg. per lb.	9	6	4	6
Minerals[a]				
Calcium, percent	.90	.75	.50	.75
Phosphorus, percent	.60	.50	.35	.50
Salt, percent	.50	.50	.35	.50
Zinc, mg. per lb.	30	30	20	30

[a] The requirements of swine for other minerals are 4 mg. of copper, 30 mg. of iron, 0.1 mg. of iodine, and 18 mg. of manganese per pound of diet.

Fortification of swine rations

The amount of fortification required in ordinary swine rations can be calculated from the values shown in Table 8. Since yellow corn and soybean meal are the main ingredients of midwestern swine rations, it is the vitamin and mineral deficiencies of these two feedstuffs that must be corrected. A combination of 80 percent yellow corn and 20 percent soybean meal has been employed as a typical mixture for the calculation of the supplementary level of vitamins and minerals. Of course the level of some supplementary nutrients varies with different rations. Vitamin additions may be quite similar for all swine rations, however, because the different ingredients of swine rations do not vary widely in vitamin content. Mineral additions, on the other hand, are more variable, and are primarily affected by the level of animal byproducts in the ration.



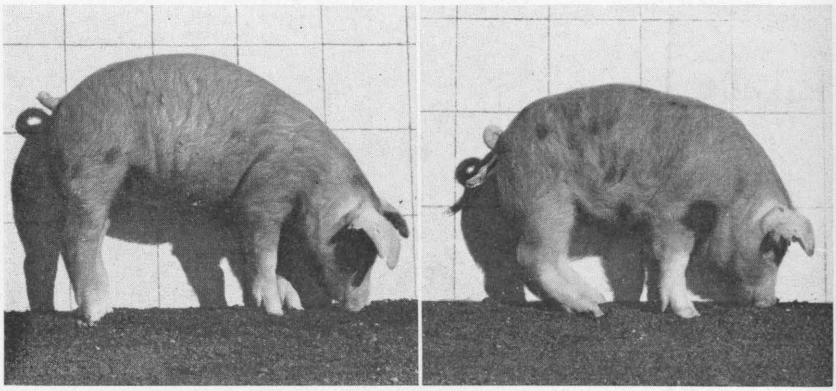
Nicotinic Acid Deficiency. The weanling pig on the left was fed a high-corn ration adequate in nicotinic acid. The pig on the right was fed a high-corn ration without supplementary nicotinic acid. This pig grew slowly, exhibited a rough hair coat, and had intermittent diarrhea. Upon autopsy, the intestinal tract was found to be ulcerated.

Vitamin fortification. Of all the important vitamins, probably vitamin A presents the greatest problem. Since vitamin A requirements are directly proportional to body weight, the total daily vitamin A

Table 8. — Vitamin and Mineral Fortification of a Typical Corn-Soybean Meal Mixture

Nutrient	Content of corn-soybean meal mixture[a]	Suggested level to add to[b]	
		Grower ration	Grower (mixing) supplement
Fat-soluble vitamins			
Vitamin A, I.U. per lb.	....	1,000[c]	4,400
or carotene, mg. per lb.	1.5[d]	....	....
Vitamin D, I.U. per lb.	....	150	660
Water-soluble vitamins			
Riboflavin, mg. per lb.	.7	.5	2.2
Pantothenic acid, mg. per lb.	4.0	2.5	11.0
Nicotinic acid, mg. per lb.	2.0[e]	7.5	33.0
Choline, mg. per lb.	430	50	220
Vitamin B_{12}, mcg. per lb.	....	8.0	35.2
Minerals			
Calcium, percent	.07	.68	3.00
Phosphorus, percent	.34	.16	.70
Trace-mineralized salt, percent	....	.5	2.2

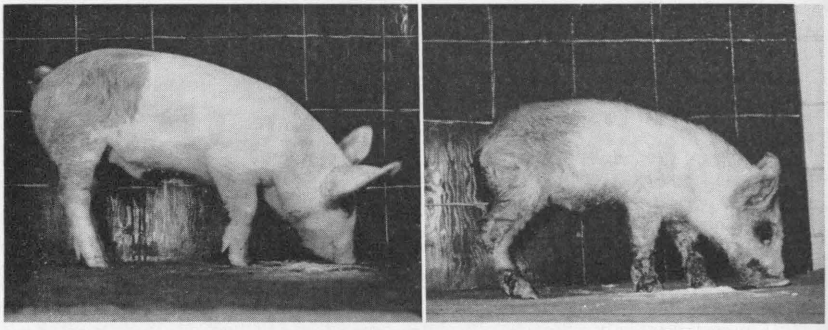
[a] A mixture of 80 percent yellow corn and 20 percent soybean meal.
[b] Vitamin additions provide levels 20 percent greater than the levels suggested in Table 7.
[c] Suggested supplementary vitamin A levels for creep or starter ration, finisher ration, breeder ration, and breeder supplement are 1,500, 750, 1,500 and 6,600 I.U. per pound, respectively.
[d] Since the vitamin A activity of yellow corn has been observed to drop sharply after storage, only 60 percent of the activity of corn is considered available for the pig.
[e] The nicotinic acid content of yellow corn is considered totally unavailable to swine.



Calcium Deficiency (rickets). The young pig on the right was fed a ration seriously deficient in calcium. Note weakened and deformed bone structure of hind legs, depressed growth, and general lack of thriftiness. Fractured vertebrae and subsequent loss of control of hind legs is a common characteristic of calcium deficiency. Normal litter-mate is at left.

intake and the recommended level per pound of ration increase with increasing body weight.

Since creep rations and pig starters contain limited quantities of yellow corn, a greater part of the dietary vitamin A must be provided in supplementary forms than in rations for more mature swine. In addition, vitamin A and provitamin A in feeds are readily destroyed. Ordinarily, yellow corn may provide a considerable part or all of the vitamin A activity required in the rations of certain classes of swine.



Zinc Deficiency (parakeratosis). The pig on the right was fed a zinc-deficient ration to produce parakeratosis. Symptoms of this condition are slowed growth, unthriftiness, very harsh and dry hair coat, and a dark brownish secretion on the fore and hind legs, hams, and belly. Note clean, smooth hair coat, normal body conformation, and improved growth of litter-mate at left. This pig was fed the same diet with supplementary zinc.

However, since yellow corn has been observed to lose as much as 60 percent of its vitamin A activity during the first seven months of storage, it is not a dependable source of vitamin A. A supplementary source of vitamin A should be added to corn-soybean meal rations in order to insure an adequate supply of this important vitamin.

Of the supplementary levels of water-soluble vitamins needed, nicotinic acid deserves particular attention. According to recent studies, much of the nicotinic acid of yellow corn exists in a bound form that is largely unavailable to swine. For this reason, yellow corn is not credited with containing any nicotinic acid, even though some feed tables indicate that corn may contain as much as 10 milligrams of nicotinic acid per pound. There is also evidence that other cereals contain nicotinic acid that is not available to the pig.

Tryptophan may be used to satisfy the need for nicotinic acid. Since corn-soybean meal rations are usually high in their tryptophan content, they would not be benefited by the addition of nicotinic acid. The vitamin and mineral requirements listed in Tables 7 and 8 are made on the premise that the diet contains the minimum tryptophan level suggested in Table 4. When other supplementary sources of amino acids (meat and bone scrap or fishmeal, for example) replace a part or all of the soybean meal, the tryptophan level may not be high enough to satisfy the need for nicotinic acid.

A vitamin supplement supplying 1 gram of riboflavin, 5 grams of pantothenic acid, 15 grams of nicotinic acid, 100 grams of choline, and 16 milligrams of vitamin B_{12} per ton of feed will adequately fortify the water-soluble vitamin content of a grower or breeder ration (values from Table 8 multiplied by 2,000). Finisher rations will be adequately fortified with 50 percent of these supplementary levels, and a double level is required in creep or starter rations. When added according to this schedule, a vitamin supplement that provides 1,500 I.U. of vitamin A and 150 I.U. of vitamin D per pound of grower ration will be adequate for all classes of swine rations.

Calcium and phosphorus fortification. Swine rations vary primarily in their calcium and phosphorus requirements; otherwise the mineral feeding levels are rather uniform for all types of rations. Corn and soybean meal mixtures are adequately fortified with calcium and phosphorus for grower and breeder rations by adding 2 percent of equal parts ground limestone and dicalcium phosphate or steamed bonemeal.

Mineral mixtures designed to supplement corn-soybean meal rations should have a calcium to phosphorus ratio of 4 or 4.5 to 1. For example, when added at 2.5 percent of the ration, a mixture containing

Table 9. — Trace-Mineral Needs in Complete Rations and Salt Mixtures

Mineral	Salt mixture,[a] recommended trace-mineral levels (percent)	Addition to complete ration (mg. per pound)
Copper	.06	1.5
Iron	.5	11.4
Iodine	.007	.17
Manganese	.75	17
Zinc	.5	11.4

[a] Salt mixture designed for adding at 0.5 and 0.35 percent of rations containing 16 and 12 percent protein, respectively.

27 percent calcium and 6 percent phosphorus will adequately supplement a corn-soybean meal ration for growing pigs.

The level of calcium and, especially, phosphorus supplementation should be reduced as feeds of animal origin are introduced into the diet. For example, 5 percent of meat and bone scrap or menhaden fishmeal in grower, finisher, or breeder rations completely eliminates the need for phosphorus supplementation. The calcium need with 5 percent meat and bone scrap may be satisfied by adding 0.5 percent of ground limestone, and the calcium need with 5 percent menhaden fishmeal may be satisfied by adding 1.0 percent of ground limestone.

Trace-mineral fortification. Recommendations for trace-mineral additions to complete swine rations and for levels in a salt mixture are listed in Table 9.

Perhaps the most frequent problem in trace-mineral fortification is the provision of supplementary zinc as protection against parakeratosis. It is easier to use a properly fortified trace-mineralized salt (see Table 9), but it may become necessary to use zinc compounds which vary in their zinc content. The zinc content of supplementary sources and the recommended level for zinc fortification of swine rations is presented in Table 10.

Table 10. — Recommended Levels of Zinc Compounds in Swine Rations

Zinc compound	Zinc content (percent)	Add per ton of complete ration to furnish 25 p.p.m. of zinc (grams)[a]
Zinc carbonate ($ZnCO_3$)	56	45
Zinc oxide (ZnO)	80	32
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	23	110

[a] For supplements, add the zinc at 4½ times the rate used for complete rations.

Iron and copper have special significance among the trace mineral elements required by swine. Iron is an essential part of hemoglobin, the oxygen-carrier of the blood, and of several enzymes. Copper is required for the proper metabolism of iron and for the synthesis of hemoglobin.

The baby pig is born with a limited store of iron and copper, and the sow's milk is too low in these elements to supply the pig's need. As a result, suckling pigs kept on concrete or wooden floors will develop anemia within 2 or 3 weeks after birth unless supplementary iron and copper are provided. Suckling pigs are usually not subject to anemia after they begin eating significant amounts of creep ration, and those on pasture satisfy their needs by nosing in the soil.

Hemoglobin levels of the baby pig normally range from 8 to 12 grams per 100 milliliters of blood. In anemia, the level may drop to 2 to 3 grams per 100 milliliters. Anemic pigs show listlessness, rough haircoat, wrinkled skin, drooping ears and tail, fat appearance, pale membranes around the mouth and eyes, and labored breathing after mild exercise. Pigs may die suddenly, but the mortality is usually low.

Nutritional anemia can be prevented by use of several iron sources, all of which provide ample copper as a contaminant or additive. Since the methods of providing iron are about equally effective for maintaining hemoglobin levels, within the normal range, the choice can be made on the basis of convenience and cost. The methods of providing iron are as follows:

1. Swab or spray the sow's udder every other day with ferrous sulfate solution (1 pound of ferrous sulfate to 3 quarts of water).
2. Use injectable iron preparations in accordance with the manufacturer's recommendation.
3. Provide access to fresh, clean sod.
4. Individual administration of iron by mouth, in the form of the solution described above, or as commercially prepared iron pills.

Antibiotics, Arsenicals, and Other Additives

Antibiotics and arsenicals are now considered standard ingredients of swine rations. Although the reason for the beneficial influence of these feed additives is not yet fully known, at least a part of the effect is related to the health of the pig.

The unhealthy pig responds more to antibiotics than the healthy pig does. Chlortetracycline (Aureomycin), oxytetracycline (Terramycin), and procaine penicillin were the first antibiotics considered to be of great value for adding to swine rations. Now it appears that certain mixtures of these antibiotics, with one another or with streptomycin,

bacitracin, or oleandomycin, are even more effective sources of antibiotic activity for swine. In addition, tylosin (Tylan) is a new and effective antibiotic which can be added to swine feeds.

Recent information indicates that certain antibiotics that have been used for several months in a herd may eventually fail to produce beneficial effects, whereas changing to a different antibiotic or combination of antibiotics may be quite effective for improving performance. This observation suggests that swine producers should periodically change antibiotic supplements, perhaps on a year-to-year basis. Such a practice seems worthwhile at least until more conclusive information is available.

Arsenicals such as arsanilic acid and 3-nitro-4-hydroxy-phenylarsonic acid may be used alone or with antibiotics in medicated feeds. For instance, therapeutic feeds containing 50 to 200 grams of antibiotic or more per ton are used with arsenicals for the prevention or control of infectious enteritis in swine. The use of arsenicals should be discontinued at least 5 days before swine are slaughtered, to eliminate the drug from edible tissues.

Recommended supplementary levels of antibiotics and arsenicals are shown in Table 11.

Copper supplementation in excess of the level required to satisfy the nutritional requirement has been observed by some to increase the rate and efficiency of gains of growing-finishing pigs. Although there is a lack of experimental evidence, it appears that the effect of copper may be similar to that of antibiotics, that is, it acts upon the bacteria of the intestinal tract. At this time, it seems that copper supplementation may be of greatest value as a therapeutic treatment for intestinal disorders that do not respond satisfactorily to antibiotics. There is no

Table 11. — Antibiotic and Arsenical Supplementation of Swine Rations

Ration[a]	Supplementary level, grams per ton		
	Antibiotic	Arsanilic acid[b]	3-nitro-4-hydroxy-phenylarsonic acid[b]
Creep or starter	40	90	22
Grower	10–20	90	22
Finisher	0 or 10	90	22
Breeder	0	0	0
Supplement (35-40 percent protein)			
Pig	50–100	450	100
Hog	0 or 50	450	100
Sow	0	0	0
Therapeutic	50–200	90	22

[a] Feeds containing an arsenical alone or with an antibiotic at 50 grams or more per ton are designated as therapeutic or medicated feeds.

[b] Never use both arsenicals in a single ration at the levels indicated.

Table 12. — Copper Compounds Used in Swine Rations

Copper compound	Percent of copper	Amount to add per ton of complete ration to furnish 125 p.p.m. of copper (grams)[a]
Cupric carbonate ($CuCO_3$)	50	250
Cupric oxide (CuO)	80	160
Cupric sulfate ($CuSO_4 \cdot 5H_2O$)	25	500

[a] For supplements, add copper at 4½ times the rate used for complete rations.

indication that copper can effectively replace the use of antibiotics as an additive in swine rations.

Copper is a toxic element that accumulates in the tissues, and symptoms of toxicity have been produced in pigs fed a ration containing 250 p.p.m. of copper. In view of this evidence, the maximum recommended level of feeding copper is 125 p.p.m. in the ration.

Several copper salts are available, but they differ in copper content. Recommended levels of adding the various copper salts to growing-finishing pig rations are presented in Table 12.

Unidentified Factors

Some studies have shown that an increase in rate of gain or feed efficiency occurs when certain feed ingredients are added to rations believed to be adequate in all known nutrients (energy, amino acids, minerals, and vitamins). In many cases it has been concluded that these feeds furnish an unidentified factor or nutrient not yet isolated and characterized. It is not clear whether there are nutrients yet to be discovered, but at the present time *it seems certain that we need not be concerned with sources of unidentified factors in formulating practical swine rations.*

Research conducted at the University of Illinois has shown that corn-soybean meal rations, adequately fortified with minerals, vitamins, and antibiotics, are not improved by additions of potential sources of unidentified factors when fed to the growing pig. Additions of dried corn distillers' solubles, dried corn distillers' grains with solubles, dehydrated alfalfa meal, dried whey, a streptomycin fermentation residue, a special fish meal, condensed fish solubles, meat and bone scrap, dried skimmilk, or corn fermentation solubles have all failed to improve a fortified corn-soybean meal ration for growing pigs.

Similarly, there is a lack of convincing evidence that any of the above feedstuffs possess unidentified-factor activity or will improve the fortified corn-soybean meal ration for sows during reproduction.

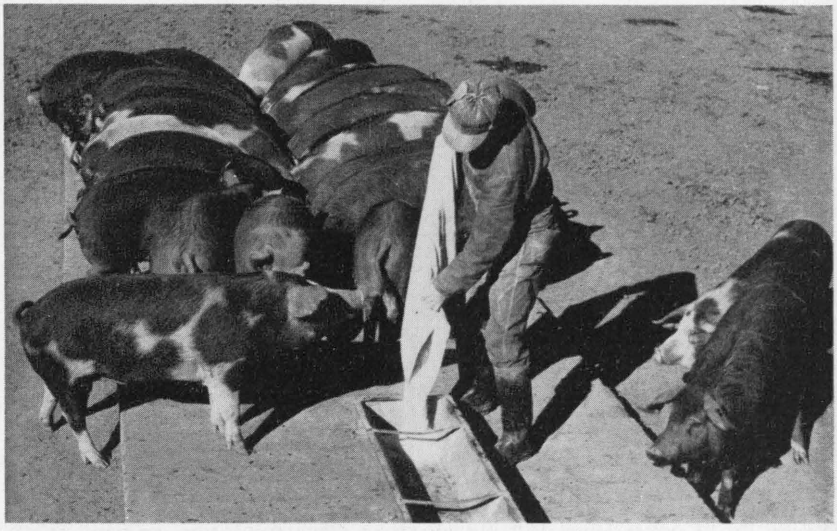
ILLINOIS SYSTEM OF SWINE NUTRITION

Some of the principal reasons underlying the development of the Illinois System of Swine Nutrition are as follows.

1. Growing and finishing pigs fed complete rations gain equally well on pasture and drylot. Values for feed efficiency verify that growing and finishing pigs consume very limited amounts of forage, indicating that drylot and pasture rations should be equally well fortified with amino acids, minerals, and vitamins.

2. Compared with alternative uses of the land, growing and finishing pigs yield an inadequate return from pasture. Each acre of good pasture has a feed-saving value of only 360 pounds when stocked at 40 pigs per acre. The breeding herd can make better use of available pasture.

3. Self-feeding bred sows and gilts is an expensive method of feeding. Although self-feeding minimizes labor expense, it requires a bulky, fibrous ration that bred sows and gilts consume at about twice the level of a corn-soybean meal ration. Therefore, the total feed cost of self-feeding is considerably greater than that of hand-feeding a concentrated ration. Over-all economy usually favors hand-feeding a concentrated ration once daily to bred sows and gilts.



Hand-feeding during gestation prevents sows from overeating and gaining excess weight.

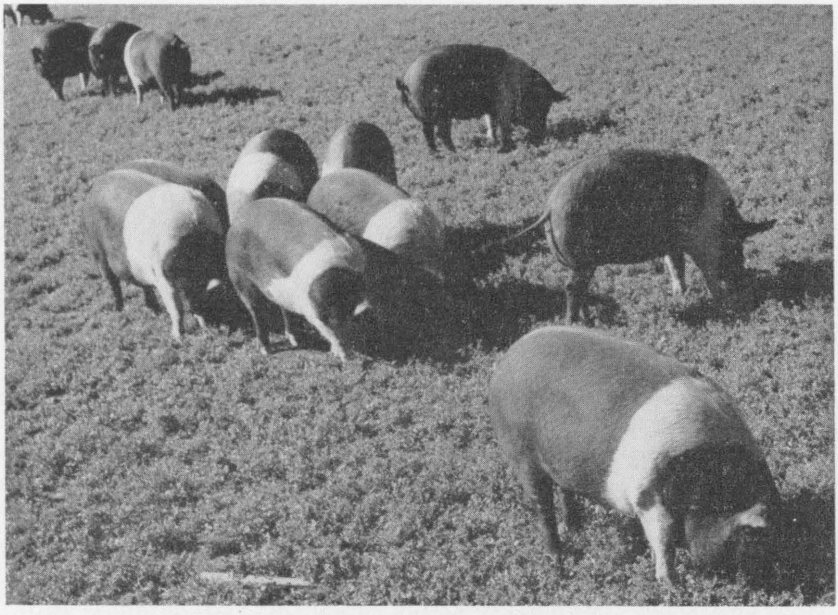
4. It is not necessary to feed a fibrous and laxative ration at farrowing time. Sows and gilts can be permitted limited or free access to a concentrated ration at farrowing without increased incidence of lactation disorders.

5. On pasture, growing and finishing pigs of all weights gain more rapidly when fed complete rations than when fed free-choice. In drylot, pigs fed complete rations show a rate and efficiency of gain at least equal and frequently superior to that of pigs fed a free-choice ration.

6. Complete rations permit better control of supplement intake. Controlling supplement intake can be a problem when the supplement is highly palatable or the grain is unpalatable. Since complete rations permit better control of supplement intake, they are often more economical than rations fed free-choice.

7. Growing and finishing pigs are more uniform when fed complete rations than when fed free-choice.

8. Complete rations permit the swine feeder to make maximum use of low-cost soybean meal as the source of supplementary amino



Pasture can be better utilized by the breeding herd than by growing and finishing pigs. Land suitable for intensive cropping will yield a higher return from grain production than when used as pasture for swine.

acids. Although soybean meal is too palatable to be self-fed free-choice with corn, it is an excellent source of the amino acids required to supplement corn. The added economy of maximum use of soybean meal is usually enough to offset normal grinding and mixing charges.

Pig-Starter and Creep Rations

A pig-starter ration for pigs from 10 to 15 pounds (weaned at two or three weeks) up to 30 pounds, and a creep ration for suckling pigs up to 30 pounds are described in Table 13.

Table 13. — Pig-Starter and Creep Rations

Ingredients	Pig-starter ration	Creep ration
Protein content, percent	22	20
Dried whey (sweet, 70 percent lactose), pounds	400	300
Soybean meal (50 percent), pounds	360	520
Dried skimmilk, pounds	400	100
Sugar (cane or corn), pounds	200	200
Rolled oats or oat groats, pounds	300	200
Yellow corn (finely ground), pounds	250	580
Animal fat, pounds	40	40
Trace-mineralized salt,[a] pounds	10	10
Ground limestone, pounds	10	20
Dicalcium phosphate or steamed bonemeal, pounds	20	20
Vitamin additions[b]		
Vitamin A, I.U.	6,000,000	6,000,000
Vitamin D_2, I.U.	600,000	600,000
Riboflavin, grams	2	2
Pantothenic acid, grams	10	10
Nicotinic acid, grams	30	30
Choline, grams	200	200
Vitamin B_{12}, milligrams	32	32
Antibiotic,[b] grams	40	40
Arsenical, grams	(c)	(c)

[a] Containing trace minerals as shown in Table 9.
[b] Vitamin and antibiotic supplements may replace the equivalent amounts of yellow corn.
[c] Added in accordance with recommendations in Table 11.

Grower and Finisher Rations

Grower and finisher rations are listed in Table 14. Illinois Ration 16 may be self-fed as a grower ration for pigs from 30 to 100 pounds; Illinois Ration 12 can be self-fed as a finisher ration for pigs from 100 to 200 pounds. Antibiotics and arsenicals are recommended in the grower-and-finisher ration as indicated in Table 11. Either the grower or the finisher ration may be used as a therapeutic feed by the addition of the necessary antibiotic and arsenical fortification.

Table 14. — Grower and Finisher Rations (Illinois Rations 16 and 12)

Ingredients	Illinois Ration 16 (pigs from 30 to 100 pounds)	Illinois Ration 12 (pigs from 100 to 200 pounds)
Protein content, percent	16	12
Ground yellow corn (medium grind), pounds	1,590	1,805
Soybean meal (50-percent),[a] pounds	360	160
Trace-mineralized salt,[b] pounds	10	7
Ground limestone, pounds	20	14
Dicalcium phosphate or steamed bonemeal, pounds	20	14
Vitamin additions[c]		
Vitamin A, I.U.	3,000,000	1,500,000
Vitamin D_2, I.U.	300,000	150,000
Riboflavin, grams	1	.5
Pantothenic acid, grams	5	2.5
Nicotinic acid, grams	15	7.5
Choline, grams	100	50
Vitamin B_{12}, milligrams	16	8
Antibiotic, grams[c]	(d)	(d)
Arsenical, grams[d]	(d)	(d)

[a] When 44-percent soybean meal is used, the amount must be increased to 400 pounds in Illinois Ration 16 and 200 pounds in Illinois Ration 12.

[b] May be added as ordinary salt and as a trace-mineral mixture. If the trace-mineralized salt contains less than 0.5 percent zinc, add a zinc supplement as indicated in Table 10.

[c] Vitamin and antibiotic supplements may replace the equivalent amounts of yellow corn.

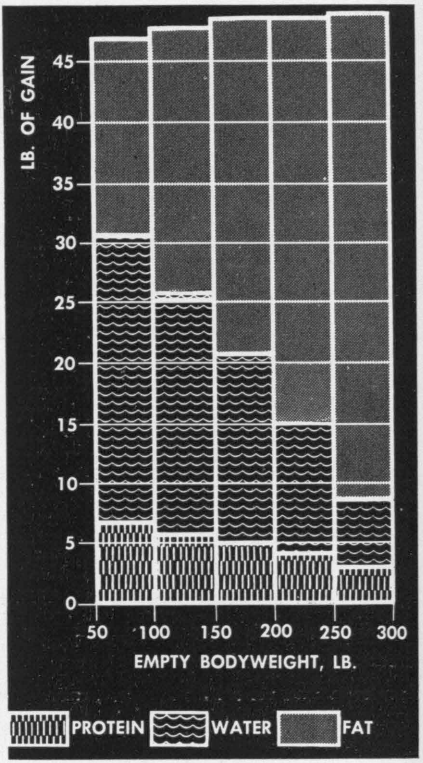
[d] May be added as indicated in Table 11. When Illinois Rations 16 and 12 are used as breeder rations, the antibiotic and arsenical should be omitted.

Limited Feeding of Finishing Swine

Research has provided evidence that the body composition of growing-finishing pigs can be affected by the feeding program. Specifically, the level of energy, or total calories, consumed will affect the nature of the bodyweight gain; that is, a moderate decrease in calories lowers the body fat content of market hogs.

Physiologically, the development of the pig may be arbitrarily divided into a growing period and a fattening or finishing period. Maximum intake of a balanced ration in early life will give maximum muscle development or body leanness. On the other hand, during finishing, or the stage between 100 and 200 pounds of bodyweight, the body gain in fat is about 5 times greater than in protein. Hence, at this stage, reduced calorie intake reduces fat deposits, yet permits growth or formation of lean tissue.

Of course, limited feed intake during the finishing period does lower the rate of gain, which slightly lengthens the feeding period. But a



Amounts of fat, protein, and water in the gain of pigs at various stages of development. Most of the water goes into lean meat. Small amounts of gain consist of ash.

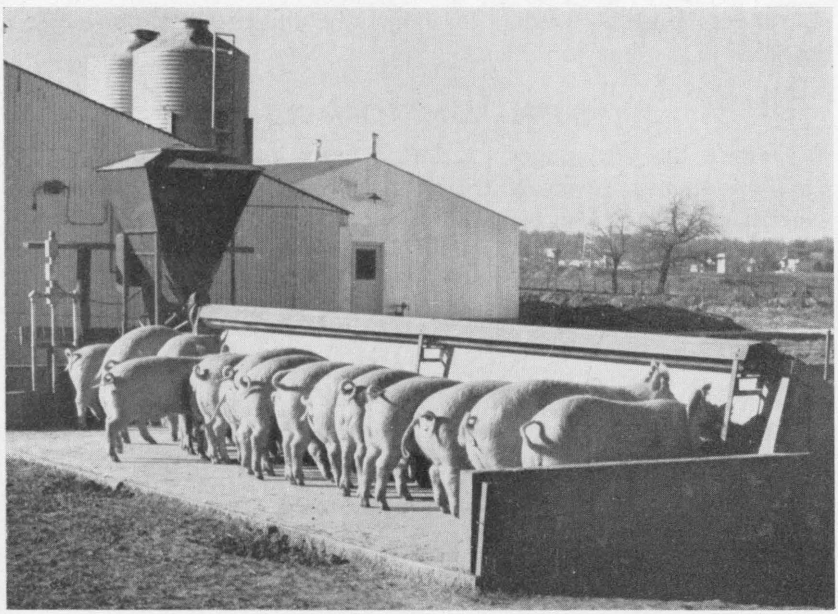
pound of gain as lean requires only about half as much feed as a pound of gain as fat. Therefore the increased body leanness, besides improving potential market value, allows the pig to make more efficient gains. This is true in spite of the longer feeding period during which extra feed is required for maintenance. Research to date indicates that the improved feed efficiency alone may justify limited feeding of finishing pigs.

Tests conducted at the University of Illinois show that limiting the feed intake of finishing hogs (those weighing 100 to 200 pounds) by feeding 70 percent of a full feed, or 5 pounds per head daily, has produced a 10-percent improvement in feed efficiency. There was an increase in the weight of lean cuts in the carcass at slaughter, and a decrease in the rate of gain by about 20 percent (the feeding period increased 10 to 14 days). Feeding at only 4 pounds per head daily increased the feed efficiency about 20 percent, with an increase of 18

days in length of feeding period. On the other hand, it has not been economical to add high levels of alfalfa meal, ground corn cobs, wheat bran, or other bulky ingredients to self-fed rations as a means of decreasing the calorie intake of finishing pigs.

For a successful limited feeding program, follow these recommendations.

1. *Full-feed* Illinois Ration 16 until pigs weigh 100 pounds.
2. At 100 pounds bodyweight, feed Illinois Ration 12 at 4 or 5 pounds per head daily and continue until the pigs reach market weight. Evidence does not favor feeding a higher level of protein, minerals, and vitamins than is used in Illinois Ration 12.
3. Feed at least 2 times per day, either mechanically or by hand. Research has not shown an advantage for more frequent feeding.
4. *Provide at least one feeding space per pig.* Self feeders can be used for limited feeding only if one feeding space per pig is provided.
5. Just as with full-fed pigs, it is important to seek a discriminating market that compensates for greater dressing percentage and carcass value. When taken off feed, limited-fed pigs will shrink less than those that have been full-fed.



An experimental mechanism for limiting feed intake automatically.

It should be noted that the advantages of limited feeding have been determined under desirable management conditions. It seems likely that unfavorable environmental conditions would minimize the benefits of a limited feed intake.

Breeder Rations (without antibiotics or arsenicals, except as therapeutic rations)

Gilts retained for breeding purposes should be removed from the feedlot at 175 to 200 pounds and hand-fed Illinois Ration 12 at a rate of 6 pounds per head daily. Sows and gilts may be self-fed Illinois Ration 12 for three weeks prior to breeding.

After females are mated, Illinois Ration 12 should be hand-fed to sows, and Illinois Ration 16 to gilts, at the rate of 4 pounds per head daily. Illinois Ration 12 may be hand-fed to both sows and gilts on pasture at the rate of 3 pounds per head daily.

During the last third (5 weeks) of the gestation period, Illinois Ration 16 should be hand-fed at 5 pounds per head daily.

At farrowing — 3 days before and 3 days after — sows and gilts may be hand-fed or given limited access (2 or 3 hours daily) to a self-feeder containing Illinois Ration 16. During lactation, both sows and gilts should be self-fed Illinois Ration 16.

All recommended feeding levels may be altered to maintain breeding stock in medium condition.

SUPPLEMENT FORMULAS

Despite the advantages of the complete rations outlined in the Illinois System of Swine Nutrition, there may be specific situations in which a supplement can be used both economically and effectively.

Suggested supplements for mixing complete rations or for hand-feeding and for self-feeding with corn are outlined in Table 15.

Table 15. — Formulas of Suggested Supplements

	Economy supplement (For mixing or hand-feeding)[a]		Sow	Pig	Hog
			(For self-feeding)		
	Grower 16% protein	Finisher 12% protein	Breeder rations	Pigs up to 100 pounds	Pigs from 100 to 200 pounds
Protein content, percent	44	42	36	40	38
Soybean meal (50-percent), pounds	1,780	1,700	1,100	1,200	1,200
Meat and bone scrap, fishmeal, or tankage, pounds	....	....	240	340	240
Dried distillers' solubles or dried whey, pounds[b]	....	....	100	100	100
Alfalfa meal	....	....	400	200	300
Trace-mineralized salt, pounds[c]	44	60	40	40	50
Ground limestone, pounds	88	120	80	80	100
Dicalcium phosphate or steamed bonemeal, pounds	88	120	40	40	50
Vitamin additions[d]					
Vitamin A, I.U., millions	13.20	13.20	6	....	....
Vitamin D_2, I.U., millions	1.32	1.32	1.2	1.2	1.2
Riboflavin, grams	4.4	4.4	3	3	3
Pantothenic acid, grams	22	22	15	15	15
Nicotinic acid, grams	66	66	20	20	20
Choline, grams	440	440	300	300	300
Vitamin B_{12}, milligrams	70	70	48	48	48
Antibiotic, grams[d]	(e)	(e)	(e)	(e)	(e)
Arsenical, grams[d]	(e)	(e)	(e)	(e)	(e)

[a] For mixing Illinois Ration 16 or 12 or for hand-feeding breeding stock or growing and finishing pigs.

[b] May be replaced with meat and bone scrap, fishmeal, or tankage.

[c] Containing trace minerals as outlined in Table 9.

[d] Vitamin and antibiotic or arsenical supplements may replace the equivalent amounts of soybean meal.

[e] Added in accordance with recommendations in Table 11.

Table 16. — Protein and Amino Acid Composition of Swine Feeds

	Protein	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Cystine	Phenylalanine	Tyrosine	Threonine	Tryptophan	Valine
							(percent)						
Barley	11.6	.58	.30	.52	.82	.50	.18	.21	.66	.32	.44	.16	.67
Corn, No. 2 yellow	9.0	.38	.22	.35	1.06	.24	.19	.13	.41	.45	.31	.06	.44
Oats	11.8	.70	.23	.55	1.00	.43	.15	.21	.65	.55	.40	.15	.62
Sorghum (Milo)	11.1	.43	.30	.50	1.26	.27	.10	.15	.48	.40	.36	.12	.56
Wheat	12.7	.75	.37	.60	.99	.42	.21	.24	.77	.54	.45	.21	.68
Cottonseed meal	40.5	4.20	1.02	1.59	2.51	1.66	.62	.84	2.11	1.13	1.38	.59	1.97
Linseed meal	35.7	3.16	.71	1.66	2.11	1.21	.63	.61	1.68	1.75	1.32	.57	2.02
Soybean meal	45.4	3.28	1.13	2.52	3.54	2.86	.59	.73	2.15	1.28	1.87	.77	2.42
Sesame meal	46.1	5.49	1.02	1.97	3.19	1.27	1.22	.62	2.18	2.06	1.68	.88	2.33
Fishmeal, menhaden	61.1	3.52	1.57	3.32	4.79	5.44	1.80	1.10	2.55	1.80	2.51	.64	3.78
Meat and bone scrap (50 percent protein)	51.0	3.63	.87	1.70	3.14	2.98	.68	.64	1.80	1.00	1.66	.36	2.46
Tankage (60 percent protein)	60.5	3.51	1.75	1.63	5.50	3.89	.67	.50	2.72	1.75	1.98	.49	3.71
Blood meal	80.2	3.38	4.22	.99	11.05	7.00	1.14	1.50	5.80	3.00	4.17	1.16	7.73
Skimmilk, dry	34.0	1.15	.84	2.15	3.18	2.45	.85	.31	1.67	1.58	1.61	.47	2.36
Whey, dry	12.1	.25	.15	.73	1.07	.70	.22	.31	.32	.20	.67	.23	.67
Alfalfa meal (17 percent protein)	17.3	.78	.40	.82	1.17	.70	.31	.30	.82	.80	.64	.33	.88
Wheat bran	15.3	1.03	.36	.59	.93	.59	.21	.25	.51	.18	.44	.30	.76
Distillers' solubles, dried	28.0	.68	.74	1.52	1.93	.84	.43	.28	1.73	.61	.92	.12	1.42

Table 17. — Vitamin and Mineral Content of Swine Feeds

	Calcium (percent)	Phosphorus (percent)	Carotene (mg. per lb.)	Riboflavin (mg. per lb.)	Nicotinic acid (mg. per lb.)	Pantothenic acid (mg. per lb.)	Choline (mg. per lb.)	Vitamin B_{12} (mcg. per lb.)
Barley	.08	.38	.20	.7	24.0[a]	3.6	520	1.5
Corn, No. 2 yellow	.02	.26	2.00	.5	10.1[b]	2.6	210	.1
Oats	.09	.39	.05	.5	8.2[a]	6.8	465	1.5
Sorghum (Milo)	.03	.30	....	.5	17.0[a]	5.0	250	(?)
Wheat	.05	.39	....	.5	27.0[a]	6.0	425	.5
Cottonseed meal	.22	1.14	....	2.5	13.0	5.4	1,350	(?)
Linseed meal	.39	.88	....	1.7	18.4	7.2	800	(?)
Soybean meal	.25	.64	.40	1.5	13.7	8.1	1,315	1.0
Sesame meal	2.00	1.60	.20	.7	7.0	4.0	700	(?)
Distillers' solubles, dried	.32	1.30	.30	6.0	56.5	9.8	2,000	.2
Fishmeal, menhaden	5.00	3.30	....	2.4	25.5	4.2	1,400	85.0
Meat and bone scrap (50 percent protein)	9.85	4.50	....	2.0	23.4	2.1	825	57.0
Tankage (60 percent protein)	6.30	3.25	....	1.1	18.6	1.1	970	30.0
Blood meal	.30	.25	....	1.5	18.0	2.3	540	(?)
Skimmilk, dry	1.27	1.00	....	9.6	5.8	16.0	625	25.0
Whey, dry	.90	.72	....	11.5	5.0	21.2	900	10.0
Alfalfa meal (17 percent protein)	1.55	.25	24.0	5.7	18.0	12.6	400	1.0
Wheat bran	.12	1.25	1.20	1.1	90.0	13.1	625	(?)
Bonemeal, steamed	29.00	14.00	....	....	....	....	....	....
Dicalcium phosphate	28.00	18.00	....	....	....	....	....	....
Soft phosphate with colloidal clay	18.00	9.00	....	....	....	....	....	....
Limestone, ground	38.00	....	....	....	....	....	....	....

[a] Probably unavailable to swine.
[b] Exists largely in bound form unavailable to swine.
Note: Question mark (?) means amounts not known.

Weight Conversions

1 pound (lb.) = 453.59 grams (gm.)
1 ounce (oz.) = 28.35 grams
1 kilogram (kg. or kilo) = 1,000 grams
1 gram = 1,000 milligrams (mg.)
1 milligram = 1,000 micrograms (mcg.)

1 mcg. per lb. = 2 mg. per ton
1 mg. per lb. = 2 gm. per ton
1 mg. per lb. = 2.2046 parts per million (p.p.m.)
.01 percent = 90.8 gm. per ton

Vitamin Activity Conversions

2 mcg. of B-carotene = 1 International Unit of Vitamin A
1 kg. of d, l calcium pantothenate = 460.0 gm. of pantothenic acid
1 kg. of d, calcium pantothenate = 920.1 gm. of pantothenic acid
1 kg. of choline chloride = 867.9 gm. of choline

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