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SWINE NUTRITION GUIDE

Nebraska and South Dakota

Cooperative Extension Service / South Dakota State University and University of Nebraska / U.S. Department of Agriculture

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Introduction

This publication is a revision of the previous swine nutrition publication prepared by the University of Nebraska and South Dakota State University. The focus of the publication continues to be on nutrient recommendations for swine. Specific factors (nutritional, environmental and managerial) that affect nutrient recommendations (Figure 1) have been considered and discussed. We believe that the identification and description of the factors in Figure 1 provide the framework for the nutrient recommendations presented in Tables 11 to 16.

Industry advisors representing various facets of the pork industry were recruited to review and challenge the concepts incorporated in this publication. Also, in situations where "gray areas" existed, these industry representatives made specific proposals or recommendations. Therefore, our ultimate goal was to use the knowledge of respected swine nutritionists who represent a cross section of the feed industry to improve the application of this publication. In preparing this publication, a priority has been to discuss some of the controversial and experimental swine nutrition issues currently being explored. The discussion of these issues has been focused to emphasize results presented in the scientific literature.

Nutrient Sources

An essential part of a sound feeding strategy is to make good decisions on which ingredients to use in the diet. Ingredients provide nutrients that pigs require for normal performance. Pigs do not require specific ingredients in their diet, but instead require energy and nutrients such as amino acids, minerals and vitamins. There are numerous ingredients available to use in pig feed. Information in this section is intended to help people make good decisions on sources of nutrients.

Energy

Pigs need energy for maintenance, growth, reproduction and

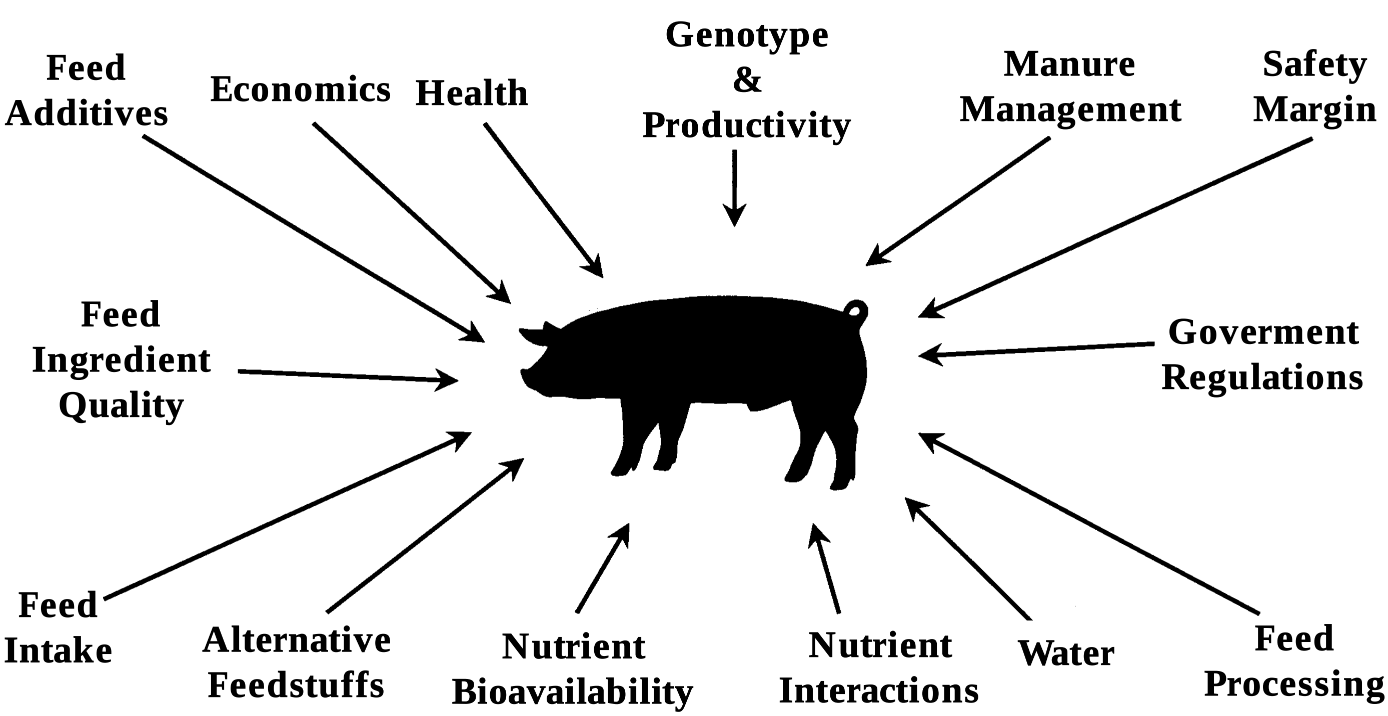

Figure 1. Factors that were considered when developing nutrient recommendations.

lactation. The bulk of the pig's energy requirement is met by carbohydrates and fats. Fats and oils are dense sources of energy, containing about 2.25 times more calories than carbohydrates. The energy content of feedstuffs and energy requirements of pigs are commonly expressed as metabolizable energy (ME). The ME content of a feedstuff is determined by subtracting energy lost in the feces, urine and gasses from the gross energy in the feedstuff.

Although many cereal grains can provide economical sources of energy for pigs in the Midwest, corn is used extensively in Nebraska and South Dakota. However, economic conditions can change, making other energy sources attractive for inclusion in pig diets.

How does one know whether another energy source is more economical?

Focus on the relative feeding value of energy sources shown in Table 1 rather than on achieving a certain feed efficiency or growth rate when evaluating alternative energy sources. Substituting milo for corn, for example, likely will reduce feed efficiency, but may reduce the

Table 1. Relative feeding values and maximum usage rates of energy sources. A * denotes no nutritional limitations in a balanced diet[a]

		Maximum recommended percent of complete diets[b]			
Ingredient (as-fed)	**Feeding value relative to corn, %[c]**	**Starter**	**Grow-finish**	**Gestation**	**Lactation**
Alfalfa meal, dehy	70 to 80	0	10	25	0
Alfalfa hay, early bloom	65 to 75	0	10	60	0
Bakery waste, dehy	110 to 120	*	*	*	*
Barley (48 lb / bu)	90 to 100	25	*[d]	*	*[e]
Beet pulp	80 to 90	0	10	50	10
Corn distillers grains w / solubles, dehy	110 to 120	5	15	40	10
Corn gluten feed	95 to 105	5	10	*	10
Corn, high lysine	100 to 110	*	*	*	*
Corn, high oil	100 to 110	*	*	*	*
Corn, hominy feed	95 to 105	0	60	60	60
Corn, yellow (> 40 lb / bu)	100	*	*	*	*
Fats / oils (stabilized)	190 to 200	5	5	5	5
Millet, proso	85 to 95	40	*	*	40
Milo, grain sorghum (> 48 lb / bu)	95 to 97	*	*	*	40
Molasses (77% DM)	55 to 65	5	5	5	5
Oats (38 lb / bu)	85 to 95	15	30	*	10
Oats, high lysine	85 to 95	30	60	*	10
Oat groats	110 to 120	*	*	*	*
Rye[f]	85 to 95	0	25	20	10
Triticale[f,g]	95 to 105	20	40	40	40
Wheat bran	80 to 90	0	10	30	10
Wheat, hard (> 55 lb / bu)[h]	100 to 110	30	*	*	40
Wheat middlings	110 to 120	5	25	*	10

[a]Assumes diets are balanced for essential amino acids, minerals and vitamins.
[b]Higher levels may be fed although performance may decrease. Economic considerations should influence actual inclusion rates.
[c]Corn = 100%. Values apply when ingredients are fed at no more than the maximum recommended % of complete diet. A range is presented to compensate for quality variation.
[d]For maximum performance, limit barley to 2 / 3 of the grain for 45 to 130 lb pigs. No limitation for pigs > 130 lb.
[e]Increased fiber in barley will reduce the ME / lb of feed. Thus, less should be used when feed intake is low.
[f]Ergot free.
[g]Low trypsin inhibitor varieties. Feed value tends to be highly variable.
[h]Coarsely ground. See the *Feed Processing* section for details.

cost of gain also. The feeding values were calculated using the ME, digestible lysine and available phosphorus content of feedstuffs. Corn, soybean meal (44% CP) and dicalcium phosphate were used as reference feedstuffs. Corn is assumed to have a feeding value of 100%. Grain sorghum (milo), for example, has a feeding value about 95% that of corn. Thus, milo can replace corn in the diet when the price of milo is less than 95% of the price of the same weight of corn. For example, if corn costs $.04/lb, milo would become more economical to feed when it is less than $.038/lb ($.04/lb x .95 = $.038/lb). The feeding value of milo is slightly less than that of corn because it has less ME and digestible lysine.

The relative feeding values apply when ingredients are included in diets in quantities no greater than those shown in Table 1. When ingredients are included in diets at lower levels than indicated in Table 1, the feeding value may increase slightly. Average daily gain and reproductive performance will not normally be reduced by replacing corn with any of the energy sources at the levels shown in Table 1. A range in feeding value is presented to account for variation in ingredient quality and individual producer goals. Also, be sure to consider factors such as storage costs and ingredient quality and availability.

■ Is carcass backfat affected by using alternate energy sources?

Backfat thickness may decrease by up to .1 inches when oats, barley, or other lower energy ingredients replace all the corn in the diet if fat is not added to make the diets isocaloric. Details on how added fat affects backfat are presented in the *Practical Applications and Outcomes* section of this publication. The fatty acid profile of backfat is made slightly more unsaturated when high-oil corn, full-fat soybeans and vegetable oils are included in the diet of finishing pigs. There has been no evidence that this has contributed to "soft pork" or a loss of carcass value. However, feeding more than 10% whole sunflower seeds to finishing pigs will result in "soft pork." Adjustments for possible changes in carcass merit have not been made in the feeding values shown in Table 1.

■ How should alternate energy sources be included in the diet?

Two methods are acceptable. Check Table 1 to see if there is a suggested limitation on the quantity of the ingredient to include in the diet. The first method is to reformulate the diet on a total or digestible lysine basis. Formulating on a digestible lysine basis is more precise. The advantage of formulating on a lysine basis is that the additional lysine in wheat and barley, for example, can be taken advantage of. This means less supplemental protein is needed in the diet. Check the tryptophan, threonine and methionine levels of the diet during formulation to ensure they are adequate. The second method is to substitute the alternate energy source for corn on a pound-for-pound basis in the diet. This procedure is acceptable for all energy sources in Table 1, except fat and molasses. These energy sources contribute no protein or amino acids to the diet, so the diet must be reformulated. ***Do not formulate diets on a protein basis because the diet may be deficient in lysine, resulting in reduced pig performance.***

■ What sources of fat are available?

Common sources of animal and vegetable fat and their ME values are listed in Table 29. Also available are blended combinations of animal fat, vegetable oil and refined or rerendered restaurant grease.

Animal fat and soybean oil are the most common fat sources used in swine diets. Animal fats in the Midwest generally include tallow, choice white grease and yellow grease. These are solid at room temperature and must be heated to about 140 to 150°F before they can be blended into the diet. In contrast, vegetable oils are liquid at room temperature and can be added to the diet without heating. Also, in general, oils are preferred over animal fat in diets for pigs weighing less than 15 lb.

Fats are available in a variety of forms including fats contained in complete diets, commercial supplements, dried fat products, whole soybeans and high-oil corn, in addition to fats obtained directly from refiners and renderers. Probably the easiest method of incorporating fat in diets made on the farm is to use full-fat soybeans or high-oil corn. Diets that contain full-fat soybeans as the sole supplemental protein source provide 3 to 4% extra fat. High-oil corn-soybean meal diets also contain 3 to 4% additional fat. Fat that is added to a swine diet should be stabilized with an antioxidant or preservative (e.g. BHT, BHA, or ethoxyquin) to avoid rancidity.

■ Are some energy sources better suited for pigs in the summer than winter?

Yes. Fat will improve pig performance more when provided in the summer than in the winter. Less heat is produced by pigs when they digest fat compared with starch or fiber. This allows pigs fed diets with added fat to continue to consume large amounts of energy during hot weather when feed intake is normally reduced. Thus, fat is generally more cost effective when fed in the summer than in the winter. In contrast, when low-energy, high-fiber feedstuffs such as alfalfa, barley and oats are digested by pigs, heat production is increased. This extra heat can be used to help maintain body temperature during the winter. Energy sources with a high fiber content are therefore more cost effective for pigs fed during winter than summer.

Does low protein corn have a lower feeding value than normal corn?

Not likely. Results from several studies indicate that the relationship between the crude protein content and lysine content of corn is poor. Thus, corn containing 7 to 7.5% CP may have the same amount of lysine as 8.5% CP corn. The lack of a good correlation between corn crude protein and lysine content indicates that one should not automatically increase the amount of protein supplement or crystalline lysine in the diet when using low protein corn. Moreover, in a 1994 study of corn produced in the Midwest, 77% of the samples contained between .23 and .28% lysine. If the lysine content of corn in a finisher diet formulated to contain .65% lysine ranges from .23 to .28%, the lysine concentration in the complete diet ranges from only .63 to .67%.

Protein and Amino Acids

Pigs of all ages and stages of the life cycle require amino acids to enable them to grow and reproduce. Amino acids are the structural units of protein. During digestion, proteins are broken down into amino acids and peptides. The amino acids and peptides are absorbed into the body and are used to build new proteins, such as muscle. Thus, pigs require amino acids, not protein. Diets that are "balanced" with respect to amino acids contain a desirable level and ratio of the 10 essential amino acids required by pigs for maintenance, growth, reproduction and lactation. Those 10 essential amino acids for swine are arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The proteins of corn and other cereal grains are deficient in certain essential amino acids. Protein supplements are used to correct the amino acid deficiencies in grains. For example, the correct combination of grain and soybean meal provides a good balance of amino acids.

Soybean meal is often the most economical source of amino acids for pigs in Nebraska and South Dakota. However, economic conditions can change, making alternative amino acid sources attractive for use in pig feed.

How does one determine whether another source of amino acids is more economical?

Use the relative feeding value of amino acid sources shown in Table 2 when considering alternative amino acid sources. These feeding values were calculated using the ME, digestible lysine and available phosphorus content of feedstuffs. Corn, soybean meal (44% CP) and dicalcium phosphate were used as reference feedstuffs. Soybean meal (44% CP) is assumed to have a feeding value of 100%. Good quality meat and bone meal, for example, has a feeding value of 110% of that of soybean meal. Thus, meat and bone meal can replace soybean meal in the diet when the price of meat and bone meal is less than about 110% of the price of the same weight of soybean meal. For example, if the meat and bone meal price is less than about $220/ton, it is a better buy than 44% CP soybean meal that costs $200/ton ($200/ton x 1.10 = $220/ton).

The relative feeding values apply when ingredients are included in diets in quantities no greater than those shown in Table 2. Average daily gain and reproductive performance will not normally be reduced by replacing soybean meal with any of the amino acid sources at the levels shown in Table 2. A range in feeding value is presented to account for variation in ingredient quality and individual producer goals. Most amino acid sources are byproducts and subject to some variation in quality, because of the processing methods used. Also, be sure to consider factors such as storage costs, handling characteristics and availability.

Are there differences in uniformity of product among protein sources?

Animal protein products vary in composition and quality more than plant protein sources. Meat and bone meal and meat meal are byproducts of the meat packing industry, and their composition depends on the animals slaughtered. Methods of processing also influence the quality of animal proteins. The rendering process (270 to 280°F) is sufficient to kill salmonella and other bacteria present in the raw material, but through improper handling, the rendered product can be recontaminanted. Buying animal proteins from a reliable supplier will reduce the impact of this quality variation on pig performance.

Many plant proteins are more uniform because they are made from a single source. Also, methods of processing plant proteins have become standardized, and the same kind of product can be produced year round. However, improper processing can occur in the production of soybean meal and other plant proteins. Also, calcium carbonate (limestone) can be added to plant protein products (up to .5%) to prevent them from becoming lumpy and to maintain good flow characteristics. The additional calcium is no problem as long as one knows how much is in the protein source.

Salmonella contamination traditionally has been associated with animal protein products. However, recent evidence indicates that grains and plant protein products can also be contaminated with salmonella.

Table 2. Relative feeding values and maximum usage rates of protein and amino acid sources. A * denotes no nutritional limitation in a balanced diet[a]

Ingredient (as-fed)	Feeding value relative to 44% CP soybean meal, %[c]	Maximum recommended percent of complete diets[b]				Comments
		Starter	Grow-finish	Gestation	Lactation	
Blood meal, spray-dried	220 to 230	3	6	5	5	low in isoleucine
Canola meal	70 to 80	0	15	15	15	antinutritional factors
Corn distillers grains w/solubles, dehy	45 to 55	5	15	40	10	poor amino acid balance
Corn gluten feed	40 to 50	5	10	90	10	high in fiber
Fish meal, menhaden	160 to 170	20	6	6	6	"fishy" taste in pork
Meat and bone meal	105 to 115	*	*	*	*	high mineral; low tryptophan content
Meat meal	130 to 140	*	*	*	*	high mineral content
Plasma proteins, spray-dried	205 to 215	*	*	*	*	
Skim milk, dried	105 to 115	*	*	*	*	low fat soluble vitamin content
Soy protein concentrate	135 to 145	*	*	*	*	
Soybean meal, 46.5% CP, dehulled	105 to 110	*	*	*	*	
Soybean meal, 44% CP	100	*	*	*	*	
Soybeans, full-fat, cooked	85 to 95	*	*	*	*	
Sunflower meal, 36% CP[d]	55 to 65	0	*	*	*	low in lysine
Whey, dried	55 to 65	30	15	5	5	high in lactose

[a]Assumes diets are balanced for essential amino acids, minerals and vitamins.
[b]Higher levels may be fed although performance may decrease. Economic considerations should influence actual inclusion rates.
[c]44% CP soybean meal = 100%. Values apply when ingredients are fed at no more than maximum recommended % of complete diet. A range is presented to compensate for quality variation.
[d]Lower protein sunflower meal sources are available. Due to variability in nutrient content, these are not recommended for use in swine diets.

What is meant by digestible amino acids?

Only a certain proportion of each of the amino acids in a feedstuff is digested and absorbed by pigs. Digestibility values for major amino acids in many feedstuffs are shown in Table 3. To calculate the digestible amino acid content of a feedstuff, multiply the total quantity of the amino acid in the feedstuff by its digestibility value in Table 3. For example, the digestible lysine content of 44% CP soybean meal containing 2.83% lysine is 2.41% (2.83 x .85). Differences in digestibility can be ignored when formulating diets that consist primarily of corn or milo and soybean meal (with no byproduct ingredients). Thus, these diets can be formulated on a total amino acid basis. When nontraditional or byproduct ingredients are used in feed, it is best to formulate the diet on a digestible amino acid basis. Otherwise, pigs may not perform as expected. Digestible lysine recommendations are given in Tables 11, 12, 13, 14, and 15.

What is meant by ideal protein or amino acid balance?

The concept of an ideal protein or ideal amino acid balance is to provide a perfect pattern of essential and nonessential amino acids in the diet without any excesses or deficiencies. This pattern is supposed to reflect the exact amino acid requirements of the pig for maintenance and growth. Therefore, an ideal protein provides exactly 100% of the recommended level of each amino acid. Although standard diets are usually formulated to meet the pig's requirement for lysine (the most limiting amino acid), excesses of many other amino acids exist. Two practical methods can provide a more ideal balance of amino acids in pig feed: Use a combination of supplemental protein sources or formulate the diet with crystalline amino acids.

Questions often are asked about whether the excess amino acids hurt pig performance and whether reduction or elimination of the excesses would improve pig performance. There is little evidence to indicate that the performance of pigs fed diets containing a more ideal balance of amino acids is better or worse than that of pigs fed practical corn-or milo-soybean meal-based diets. However, if excess amino acids are reduced, nitrogen excreted through the urine and feces will be reduced, meaning that less nitrogen is in the manure. This will reduce the amount of land

Table 3. Apparent digestibility (%) of amino acids[a] at the terminal ileum[b, c]

Ingredient	Lys	Trp	Thr	Met	Cys
Grains					
Barley	68	70	66	80	76
Corn	***66***	***64***	***69***	***86***	***78***
Milo	***62***	***75***	***68***	***81***	***79***
Oat groats	79	80	76	85	80
Oats	70	72	59	79	69
Rye	64	67	59	76	74
Triticale	76	74	69	85	83
Wheat	73	81	72	85	84
Wheat bran	69	65	60	76	70
Wheat middlings	75	77	69	82	82
Protein Sources					
Alfalfa meal, 17% CP	50	39	51	64	20
Blood meal, spray-dried	91	88	86	85	81
Canola meal	74	73	69	82	79
Corn gluten feed, 23% CP	51	47	57	79	53
Dried distillers grains with solubles	47	50	55	72	57
Dried skim milk	91	90	85	92	81
Dried whey	82	78	79	84	86
Feather meal	54	63	74	65	71
Fish meal, Menhaden	89	79	85	88	73
Meat and bone meal	74	60	70	79	55
Meat meal	83	73	79	85	55
Plasma proteins, spray-dried	87	92	82	64	—
Soybean meal, 48.5% CP	***85***	***81***	***78***	***86***	***79***
Soybean meal, 44.0% CP	***85***	***80***	***78***	***86***	***77***
Soybeans, extruded	81	75	77	78	76
Sunflower meal, 42% CP	74	76	71	87	74

[a]Amino acid abbreviations: Lys = lysine, Trp = tryptophan, Thr = threonine, Met = methionine, and Cys = cystine.
[b]Most common ingredients are in bold-italic.
[c]From NRC. 1998. Nutrient Requirements of Swine. 10th Edn. National Academy Press, Washington, DC.

required to properly manage the nitrogen in the manure. Unless there is a strong incentive to reduce nitrogen in the manure, choose sources of amino acids that will produce the lowest cost gain.

■How should alternate amino acid sources be included in the diet?

Check Table 2 to see if there is a suggested limitation on the quantity of the ingredient to include in the diet. Then reformulate the diet on a total or digestible lysine basis and check that the tryptophan, threonine and methionine levels are adequate. Formulating on a digestible lysine basis is the most precise. ***Do not formulate diets on a protein basis because the diet could be deficient in lysine and (or) other amino acids, resulting in reduced pig performance.***

■When is it economical to use crystalline amino acids in swine diets and how can they be used?

It depends on the price of the crystalline amino acids and the prices of grain and supplemental protein sources. The use of L-lysine•HCl as a source of crystalline lysine is often economically sound. Crystalline methionine is commercially available and inexpensive. Crystalline tryptophan and threonine can be purchased in feed-grade forms, but currently they are rather expensive. Crystalline lysine and tryptophan together in the same source is now commercially available. Other sources combining these crystalline amino acids as well as others may be developed in the future.

Three pounds of L-lysine•HCl (containing 78% pure lysine) plus 97 lb of corn contribute the same amount of digestible lysine as 100 lb of 44% CP soybean meal. If L-lysine•HCl is used, one must monitor dietary tryptophan, threonine and methionine levels and maintain sufficient intact protein (e.g., soybean meal) in the diet to meet the requirements for these amino acids. Greater reductions of intact protein may be possible when using products containing both crystalline lysine and tryptophan. As when adding L-lysine•HCl, monitor dietary threonine and methionine levels when using these products. The level of crystalline amino acids supplemented will depend on the feeds used in the formulation and is usually dependent on the second limiting amino acid. That amino acid changes depending on the ingredients used. In most swine diets lysine is first limiting and either tryptophan or threonine is second limiting. However, starting pig diets containing large amounts of plasma proteins and blood meal need to be supplemented with crystalline methionine.

Use caution when considering crystalline amino acids as substitutes for intact protein in gestation or lactation diets. Gestating sows are usually fed once per day, and research in limit-fed pigs indicates that crystalline amino acids are used less efficiently than they are when pigs consume feed several times per day. There is evidence that in some circumstances lactation diets can be co-limiting in lysine and another amino acid(s). In these circumstances, replacement of intact protein with lysine alone could lead to a deficiency of other amino acids. An amino acid deficiency causes reduced litter weight gain and sow lactation feed intake.

A factor not traditionally considered when evaluating the use of crystalline amino acids in swine diets is nitrogen content of the manure. As stated previously, reducing excess amino acids will result in a decrease in the nitrogen content of the manure. When incorporated properly, the use of crystalline amino acids will accomplish that without affecting growth performance. This means the producer needs fewer acres to spread the manure on and potentially less odor.

To ensure proper distribution in the complete feed, amino acids must be combined with a carrier to achieve a minimum volume before they are added to the mixer (see *Feed Processing* section).

■Can soybean meal serve as the sole source of supplemental protein in the diet?

Yes, but only for pigs heavier than about 25 lb. Younger, lighter pigs have a reduced ability to use the complex proteins found in soybean meal. In addition, starting pigs may develop an allergic reaction to certain proteins in soybean meal, causing difficulty in digesting and utilizing feed. It is desirable to include less allergenic, highly digestible amino acid sources in diets for starting pigs; for example, spray-dried plasma proteins and blood meal, menhaden fish meal, dried whey, and(or) soy protein concentrate, although soybean meal would be a less expensive source of amino acids.

Minerals

Minerals serve many important functions in pig nutrition. These range from structural functions in bone to a wide variety of chemical reactions essential for maintenance, growth, reproduction and lactation. Pigs require at least 13 minerals. Of these calcium, chloride, copper, iodine, iron, manganese, phosphorus, selenium, sodium and zinc should routinely be added to the diet. Practical corn-or milo-soybean meal based diets contain sufficient levels of magnesium, potassium and sulfur.

■What are the major sources of minerals for swine?

Major sources of the minerals commonly added to swine diets are listed in Table 4. In addition, the relative bioavailability of minerals from several sources are listed in the table to ensure precise diet formulation. Base decisions on which source of trace mineral to use primarily on price per unit of available element. The use of selenium in animal feeds is regulated by the FDA.

■What is meant by available phosphorus?

Like amino acids, a certain proportion of the phosphorus in a feedstuff cannot be used by pigs. Most of the phosphorus in corn and other feed grains, soybean meal, oilseed meals and other byproducts of seed origin occurs as the organic complex phytate. Phosphorus in this form is poorly available to pigs because they lack the enzyme phytase, which releases the phosphorus. Research indicates there are large differences in phosphorus availability among feedstuffs. In the most precise type of diet formulation, adjustments are made for these differences. That is, diets are formulated on an available rather than total phosphorus basis. When diets contain primarily corn or milo and soybean meal it is appropriate to formulate them on a total phosphorus basis. However, when nontraditional or byproduct ingredients are used in pig feed, formulate the diets on an available phosphorus basis. See Tables 11, 12, 13, 14 and 15 for available and total phosphorus recommendations for complete feeds. Table 29 contains the available phosphorus content of several ingredients.

Supplementing swine diets with phytase has been effective in improving the availability of phosphorus in corn and soybean meal. This means less inorganic phosphorus (e.g., from dicalcium phosphate) is needed in the diet, resulting in less phosphorus in the manure. While most manure management plans are based on nitrogen, there is increasing interest in basing them on phosphorus. This is in an effort to decrease phosphorus buildup in the soil, and to reduce the potential for phosphorus runoff into lakes and rivers. However, land requirements for a phosphorus-based swine manure management plan are at least twice that required for a nitrogen-based plan. Therefore, depending on the cost of manure application and whether the manure management plan is based on nitrogen or phosphorus, the use of phytase in swine diets may be economical.

The development of low phytate phosphorus varieties of corn is another method producers can use to reduce phosphorus excretion and use of inorganic phosphorus. Preliminary data indicate that the use of these varieties can reduce phosphorus excretion and the use of inorganic phosphorus and may improve the digestibility of other nutrients. However, factors such as yield drag, cost of raising the crop, etc, must be considered when deciding whether to use low phytate phosphorus corn.

■What are chelated or

Table 4. Mineral sources and bioavailabilities[a,b]

Mineral element	Source	Formula	Content of element, %	RB, %[b]	Comments
Calcium	***Calcium carbonate***	***$CaCO_3$***	***38.5***	***90 to 100***	***Limestone*** ***Oyster shell***
	Curacao phosphate		35.1	Unk[d]	
	Defluorinated rock phosphate		32	90 to 100	< 1 part F to 100 parts P
	Dicalcium phosphate	***$CaHPO_4 \cdot 2H_2O$ and $CaHPO_4$***	***20 to 24***	***90 to 100***	***Grey granules***
	Monocalcium phosphate	***$CaH_4(PO_4)2 \cdot H_2O$***	***17***	***90 to 100***	
	Soft rock phosphate		16	70	Colloidal phosphate
	Steamed bone meal		29.8	Unk	
Copper	Cupric acetate	$Cu(C_2H_3O_2)_2$	100		
	Cupric carbonate	$CuCO_3 \cdot Cu(OH)_2$	50 to 55	60 to 100	Dark-green crystals
	Cupric chloride, tribasic	$Cu_2(OH)_3Cl$	58	100	Green crystals
	Cupric oxide	CuO	75	0 to 10	Black powder or granules; not recommended as a copper supplement
	Cupric sulfate	***$CuSO_4 \cdot 5H_2O$***	***25.2***	***100***	***Blue or ultramarine crystals***
Iodine	***Ethylenediamine dihydroiodiode (EDDI)***	***$NH_2CH_2CH_2NH_2 \cdot 2HI$***	***79.5***	***100***	***White***
	Calcium iodate	***$Ca(IO_3)_2$***	***64.0***	***100***	***Stable source***
	Potassium iodide	KI	68.8	100	Used in iodized salt (.01%)
Iron	Ferric chloride	$FeCl_3 \cdot 6H_2O$	20.7	40 to 100	
	Ferric oxide	Fe_2O_3	69.9	0	Red - used as a coloring pigment; not recommended as an iron supplement
	Ferrous carbonate	$FeCO_3$	38	15 to 80	Beige
	Ferrous fumarate	$FeC_4H_2O_4$	32.5	95	Reddish-brown
	Ferrous oxide	FeO	77.8	Unk	Black powder
	Ferrous sulfate (1 H_2O)	***$FeSO_4 \cdot H_2O$***	***30***	***100***	***Green to brown crystals***
	Ferrous sulfate (7 H_2O)	$FeSO_4 \cdot 7H_2O$	20	100	Greenish crystals
Manganese	Manganous dioxide	MnO_2	63.1	35 to 95	Black powder
	Manganous carbonate	$MnCO_3$	46.4	30 to 100	Rose-colored crystals
	Manganous chloride	$MnCl_2 \cdot 4H_2O$	27.5	100	Rose-colored crystals
	Manganous oxide	***MnO***	***60***	***70***	***Green to brown powder***
	Manganous sulfate	***$MnSO_4 \cdot H_2O$***	***29.5***	***100***	***White to cream powder***
Phosphorus	Curacao phosphate		14.2	40 to 60	
	Defluorinated rock phosphate		18	85 to 95	< 1 part F to 100 parts P
	Dicalcium phosphate	***$CaHPO_4 \cdot 2H_2O$ and $CaHPO_4$***	***18.5***	***95 to 100***	***Grey granules***
	Monocalcium phosphate	***$CaH_4(PO_4)_2 \cdot H_2O$***	***21.1***	***100***	
	Monosodium phosphate	$NaH_2PO_4 \cdot H_2O$	24.9	100	Large white crystals
	Soft rock phosphate		9.1	30 to 50	
	Steamed bone meal		12.5	80 to 90	
Selenium	Sodium selenate	$Na_2SeO_4 \cdot 10H_2O$	21.4	100	White crystals
	Sodium selenite	***Na_2SeO_3***	***45***	***100***	***White to light pink crystals***
Zinc	Zinc carbonate	$ZnCO_3$	56	100	White crystals
	Zinc oxide	***ZnO***	***72***	***50 to 80***	***Grayish powder***
	Zinc sulfate (1 H_2O)	***$ZnSO_4 \cdot H_2O$***	***35.5***	***100***	***White crystals***
	Zinc sulfate (7 H_2O)	$ZnSO_4 \cdot 7H_2O$	22.3	100	

[a]Most common sources are in bold-italic.
[b]From NRC. 1998. Nutrient Requirements of Swine. 10th Edn. National Academy Press, Washington, DC.
[c]RB = relative bioavailability. Values are expressed relative to the bioavailability in the most common source.
[d]Unk = unknown.

proteinated trace minerals?

Trace minerals generally are added to swine diets as inorganic salts, such as copper sulfate, iron sulfate, zinc oxide, etc. Chelated forms of some trace minerals have become available. Trace minerals are bound to a compound such as a protein or individual amino acid to form a chelate (e.g. zinc-methionine and iron-lysine). The chelate is designed to enhance the absorption of the trace mineral from the small intestine. Research in pigs, however, has demonstrated that the bioavailability of the minerals in chelated forms is not always greater and is sometimes lower than the bioavailability of elements in inorganic salts. Usually the inorganic forms of trace minerals are most economical.

■How important are dietary electrolytes?

Electrolytes (minerals) are essential to maintaining water balance in pigs. Electrolyte balance is particularly important for starting pigs, because they are more susceptible to diarrhea, which can cause severe dehydration. The major elements involved in electrolyte balance are sodium, chloride, potassium, magnesium and calcium, but sodium, chloride and potassium predominate. We do not recommend including electrolytes in swine diets at levels exceeding those shown in Tables 11, 12, 13, 14, 15 and 16 even in times of stress, such as those associated with weaning and feeder pig sales and transfers.

Vitamins

Vitamins are organic compounds that are required in very small amounts for maintenance, growth, reproduction and lactation. Some vitamins (thiamin, vitamin B_6, and vitamin C) probably do not need to be included in the diet because they are synthesized from other compounds in the body or by microorganisms in the digestive tract, or grain-soybean meal diets contain sufficient amounts to meet the pig's requirement. Vitamins are classified as either fat soluble (vitamins A, D, E and K) or water soluble. The water soluble vitamins routinely added to all swine diets include niacin, pantothenic acid, riboflavin and vitamin B_{12}. In addition, biotin, choline and folic acid routinely are added to diets for breeding swine.

Vitamin potency in feed and manufactured products will decrease with exposure to light, high humidity, heat, rancid fat and oxygen. Vitamins can be destroyed when in contact with minerals over a prolonged period of time. For best results, store basemixes and trace mineral-vitamin premixes in a cool, dry, dark place and use them within 30 days of purchase. Premixes containing only vitamins can be stored longer.

■What are the major sources of vitamins for pigs?

Major sources of supplemental vitamins for pigs are listed in Table 5. Although vitamins are present in grains and protein supplements, it is usually better to rely on vitamins supplied by sources in Table 5. The reason is that vitamins in grains and protein sources may be lost during storage, drying and processing or may be unavailable to the pig. An exception is made for choline, folic acid and biotin. We believe that the amounts of these vitamins that are present in grains and protein sources are sufficient for normal growth, but they should be supplemented in diets for breeding swine. All the vitamin recommendations in this publication are added levels.

■Is there a difference between synthetic and natural forms of vitamin E?

Yes. The most common form of synthetic vitamin E used is dl-α-tocopheryl acetate. It is very stable during storage and / or in mixed feed. The natural form of vitamin E (d-α-tocopherol) sometimes is used. It is less stable and exhibits a decline in activity over time. However, it has a higher relative biological activity than dl-α-tocopheryl acetate (Table 5). In one study, starting pigs performed the same whether dl-α-tocopheryl acetate or d-α-tocopherol in an encapsulated matrix was included in the feed. However, d-α-tocopherol was more effectively absorbed than dl-α-tocopheryl acetate. Make decisions on which source of vitamin E to use primarily on price per unit of available vitamin and on how long the vitamin supplement or feed will be stored.

Bioavailability

Nutrients present in feedstuffs are not fully available to pigs. Generally, only a portion of each nutrient can be used. This is because feedstuffs are not completely digested and because nutrients occasionally occur in forms that pigs are not able to use. The portion that is absorbed in a form suitable for use is said to be bioavailable. The amount that is bioavailable depends primarily on the feed ingredient itself. For example, the iron in ferrous sulfate is much more bioavailable than the iron in ferric oxide. However, there are other factors that also can influence bioavailability. These include the physiological and nutritional status of the animal (e.g., if an animal is deficient in a nutrient, bioavailability is often increased) and interactions among nutrients (e.g., high calcium levels reduce zinc bioavailability).

Precise diet formulation recognizes differences in nutrient bioavailability among feedstuffs and is, therefore, based on the bioavailable content rather than the total content of nutrients. Of course, nutrient

Table 5. Vitamin sources and bioavailabilities[a]

Vitamin	1 IU equals	Sources	RB, %[b]	Comments
Vitamin A	***.3 mg retinol or .344 μg vitamin A acetate or 1 USP unit***	***Vitamin A acetate (all-trans retinyl acetate)***	***Unk[c]***	***use coated form or cross-linked stabilized beadlet form***
	.55 μg vitamin A palmitate	Vitamin A palmitate	Unk	used primarily in food
	.36 μg vitamin A propionate	Vitamin A propionate	Unk	used primarily in injectibles
Vitamin D	.025 μg cholecalciferol or 1 USP unit or 1 ICU	Vitamin D_3 (cholecalciferol)	Unk	coated form more stable
Vitamin E	***1 mg DL-α-tocopheryl acetate***	***dl-α-tocopheryl acetate (all rac)***	***100***	
	.735 mg *d*-α-tocopheryl acetate	*d*-α-tocopheryl acetate (RRR)	136	
	.909 mg *dl*-α-tocopherol	*dl*-α-tocopherol (*all rac*)	110	very unstable
	.671 mg *d*-α-tocopherol	*d*-α-tocopherol (RRR)	149	very unstable
Vitamin K	1 Ansbacher unit = 20 Dam units = .0008 mg menadione	Menadione sodium bisulfite (MSB)	100	coated form more stable
		Menadione sodium bisulfite complex (MSBC)	100	legal for poultry only
		Menadione dimethylpyrimidinol bisulfite (MPB)	***100***	
Riboflavin	No IU-use μg or mg	Crystalline riboflavin	100	spray-dried
Niacin	No IU-use μg or mg	Niacinamide	100	fine crystalline powder
		Nicotinic acid	***100***	***fine crystalline powder***
Pantothenic acid	***No IU-use μg or mg***	***d-calcium pantothenate***	***100***	spray-dried
		dl-calcium pantothenate	50	
		dl-calcium pantothenate - calcium chloride complex	50	
Vitamin B_{12}	1 μg cyanocobalamin or 1 USP unit or 11,000 LLD (*L. lactis* Dorner) units	Cyanocobalamin	Unk	crystalline powder dilution
Choline	No IU-use μg or mg	Choline chloride	Unk	hygroscopic
Biotin	No IU-use μg or mg	*d*-biotin	Unk	spray-dried
Folic acid	No IU-use μg or mg	Folic acid	Unk	spray-dried

[a]Most common sources are in bold-italic.
[b]RB=relative bioavailability. Values are expressed relative to the bioavailability in the most common source.
[c]Unk = unknown.

recommendations should also be stated in terms of bioavailable requirements, but for many nutrients there is an inadequate amount of data about requirements in bioavailable terms to permit this. In practice, nutrients that have the largest effect on diet cost (e.g., amino acids and phosphorus) usually are formulated on a bioavailable basis.

To enable readers to formulate diets on a bioavailable basis and to evaluate more critically ingredients for possible inclusion in swine diets, tables of amino acid, mineral and vitamin bioavailabilities are provided (Tables 3, 4, and 5). The values for amino acid bioavailability are based on apparent digestibilities at the terminal ileum of growing pigs. Although apparent digestibilities can differ somewhat from true bioavailabilities for some feedstuffs, these digestibilities are widely accepted as similar to bioavailabilities for most common feedstuffs used in the USA. Crystalline amino acids (i.e., L-lysine • HCl, L-tryptophan, L-threonine, and DL-methionine) are assumed to be 100% bioavailable. Most of the values for minerals and vitamins are based on growth assays using slope-ratio procedures and are relative bioavailabilities (i.e., they are relative to a standard source that is assigned a value of 100%). The bioavailable phosphorus content of feedstuffs is contained in Table 29.

Nutrient Interactions

The absolute requirement for one nutrient can be influenced by the amounts of other nutrients in the diet. There will always be an excess concentration of some nutrients when using common ingredients. In some cases, excesses of one nutrient may cause an undesirable interaction with another nutrient. Interactions can include mineral with mineral, mineral with vitamin, vitamin with amino acid, and amino acid with amino acid. Although there are many nutrient interactions, only a few are of practical importance when formulating swine diets with common ingredients. However, others may be important when using nontraditional ingredients. Some of the more frequent nutrient interactions that can cause problems are discussed in this section.

Calcium and Phosphorus

Calcium is the most deficient mineral in diets formulated with cereal grains and oilseed meals. Phosphorus is also deficient in plant materials. Furthermore, much of the phosphorus in plants occurs as the organic complex phytate which renders it mostly unavailable to the pig. Thus, it is necessary to supplement diets with both calcium and phosphorus for satisfactory performance. Although the level of each nutrient is important, the ratio of calcium to phosphorus may be more important in certain situations. The calcium:phosphorus ratio in grain and oilseed meal-based diets should normally be between 1:1 to 1.5:1, although wider ratios may be acceptable under certain circumstances. However, caution is necessary because high levels of calcium interfere with phosphorus absorption. At marginal levels of phosphorus, the ratio must be close to 1:1. As long as both calcium and phosphorus levels meet or exceed recommended levels, a ratio less than 1:1 is not detrimental, but usually results in more costly diets. At excess levels of phosphorus (implying considerable inorganic phosphorus is included) the calcium to phosphorus ratio may exceed 1.5:1. The *total* calcium to *available* phosphorus ratio in the diet needs to be close to 2:1.

Calcium and Zinc

The absorption of zinc is affected by the level of calcium in the diet. High levels of calcium included in diets with high levels of phytate cause zinc to be bound in a complex that renders both zinc and phosphorus unavailable to the pig. When formulation of diets results in high levels of calcium, zinc must be increased. The levels of zinc suggested in this publication assume reasonable levels of calcium.

Copper, Iron and Zinc

These three minerals are involved in interactions; however, the effects of increasing levels of one or more of these minerals in the diet are not consistent.

Excess iron and zinc reduce copper availability. Extremely high levels of zinc can lead to a copper deficiency, which is characterized by anemia. Because of metabolic interactions, zinc sources with relatively low bioavailability (e.g., zinc oxide) might be superior to sources with high availability (e.g., zinc sulfate) when including zinc at high levels for nonnutritional purposes.

High levels of copper (e.g., 250 ppm) are used as a growth promotant, and these levels are not toxic unless diets are deficient in iron and zinc (and high in calcium). When 500 ppm of copper has been fed there has been mixed success in lowering stored levels of copper by increasing zinc levels in the diet.

Vitamin E and Selenium

The interaction between vitamin E and selenium is related to the protection of tissues against the detrimental effects of peroxides. Vitamin E helps protect against peroxide damage by scavenging free radicals before they can attack cellular membranes and cause oxidative damage. Selenium is a component of glutathione peroxidase, an enzyme involved in the destruction of peroxides. Although vitamin E and selenium may not be substituted for one another, the interaction between the two nutrients results from the sparing effect of one on the need for the other. In addition, vitamin E plays an antioxidant role in feed. Trace minerals, such as copper, zinc, and iron increase oxidation and thus increase the destruction of vitamin E in stored feed. Other natural antioxidants, such as vitamin A, are also attacked and can spare vitamin E in this role. Factors that affect the amount of vitamin E and selenium to supplement are the level and type of dietary fat, presence of antioxidants in the feed, level of trace mineral inclusion and length and conditions of feed storage.

Amino Acids

Absolute requirements for individual amino acids can be determined assuming that all amino acids are provided in sufficient quantities without excesses (i.e., ideal protein ratios). However, when least-cost or best-cost diets are formulated, excesses of some amino acids are inevitable. The first limiting amino acid in these formulations (the amino acid for which the target level is last to be met as the amino acid source is increased in the diet) is usually lysine, but can be tryptophan, methionine, threonine, isoleucine or valine at certain growth phases and with certain combinations of ingredients. The requirements for the essential amino acids methionine and phenylalanine depend on the level of the nonessential amino acids, cystine and tyrosine, respectively. Methionine can be converted to cystine, and up to 50% of the requirement for total sulfur amino acids (methionine + cystine) can be provided by cystine. The same situation exists for phenylalanine and tyrosine (up to 50% of the requirement for total aromatic amino acids [phenylalanine and tyrosine] can be provided by tyrosine). However, neither cystine nor tyrosine can be converted to the essential amino acids methionine and phenylalanine.

• *Amino Acid Imbalance*

This occurs when an essential amino acid other than the one that is first limiting is supplied in excess. It may occur as a result of adding a crystalline amino acid or a protein source high in that amino acid. The result is that the first limiting amino acid, which is supplied at a level that should be sufficient, now becomes deficient. Feed intake is reduced, and, as a result, there is a proportional reduction in pig gain. To correct the situation, the level of the excessive amino acid must be decreased or the level of the first-limiting amino acid must be increased.

• *Amino Acid Toxicity*

This condition resembles an amino acid imbalance in that an amino acid other than the first limiting amino acid is supplied in excess quantity. However, an amino acid toxicity can not be corrected by adding higher levels of the first limiting amino acid. Toxicities invariably are caused by excess additions of crystalline amino acids and are corrected by reducing or eliminating the amino acid additions. While methionine and tryptophan are two amino acids that can cause toxicities, lysine and threonine rarely cause toxicity problems. Lower feed intake and pig gains can be expected as a result of amino acid toxicities.

• *Amino Acid Antagonism*

This condition results from the excess of one amino acid that has a negative effect on a structurally similar amino acid. Because structurally similar amino acids compete for the same absorption and transport sites in the small intestine, high levels of one amino acid may create a metabolic deficiency of the other amino acid, even when that second amino acid is supplied at the required level in the diet. Lysine and arginine and leucine and isoleucine are examples of structurally similar amino acids that compete for absorption sites. An antagonism results in lower feed intake, lower pig gains and poorer feed efficiency. Antagonisms rarely are a problem in pigs fed grain and oilseed meal diets.

Ingredient Quality

Quality of the ingredients used in swine diets can have a large effect on performance. Test weight of grains, nutrient variability of byproducts and presence of mycotoxins all affect the feeding value of ingredients. However, when properly formulated, diets containing byproducts and weather-stressed grains can provide an economic alternative for swine producers.

What is the relationship between the test weight of grain and feeding value?

Most previous research indicates low test weight grains contain more protein and fiber and less starch and ME than normal grains, implying that low test weight grains have a lower feeding value than normal grains (Table 6). However, more recent research on corn suggests there is a poor relationship between test weight and nutritional value. There is general agreement that pig growth rate seldom is affected by grain test weight as long as the test weight is not reduced by more than about 25%. However, if low test weight grain has less ME, pigs will compensate by increasing feed consumption, resulting in a poorer feed efficiency. The negative effect on feed efficiency can range from 0 to 15%, depending on how much the test weight is lowered and which grain is fed. Fat can be added to diets containing low test weight grains to offset a possible reduction in pig performance.

In general, it is best to use low test weight grains in finishing and gestation diets (if they are free of mycotoxins) because older pigs use lower energy feedstuffs better than younger pigs. The feeding level during gestation may have to be increased to compensate for the lower energy value of the light test weight grain. Also, include low test weight grains in the diet by weight, not volume. Therefore, scales on mixing equipment are necessary to make diets properly.

• *Low Test Weight Corn*

Corn weighing between 40 to 56 lb / bushel has the same feeding value for growing-finishing swine when compared on an equal moisture basis. When test weight drops below about 40 lb / bushel, growth rate and feed efficiency may decrease by 5 to 10%.

• *Low Test Weight Milo*

Late planting, a cool growing season, or an early frost can lead to low test weight milo. It should be used only in growing, finishing and gestation diets. According to a recent study, there was no difference in gain or feed efficiency for growing-finishing pigs fed either 45

Table 6. Normal test or bushel weight of grains

Grain	lb/bushel
Barley	48
Corn	56
Milo	56
Oats	38[b]
Wheat	60

[a]1 bushel (U.S.) = 32 quarts.
[b]Although 32 lb test weight is the standard, oat producers are paid on a 38 lb / bushel basis.

or 55 lb / bushel milo. However, feeding 35 lb / bushel milo resulted in 13% and 6% poorer feed efficiencies in the growing and finishing phases, respectively. For milo weighing less than 45lb / bushel, use local prices to determine what price the milo has to be to offset the expected poorer feed efficiency.

- *Low Test Weight Wheat*

Research indicates finishing pigs fed 45 to 51 lb / bushel wheat were 7.3% less efficient than those fed 59 lb bushel wheat. When determining the economics of feeding low test weight wheat, assume it to have a feeding value of about 90% of normal wheat.

- *Low Test Weight Barley*

In growing-finishing pigs, expect about a 5% increase in the amount of feed required per pound of gain for every 2.5 lb reduction in barley test weight from 49 to 44 lb / bushel, with an additional 7% poorer feed efficiency for 39 lb / bushel barley. If the barley is scab-infested, it should be fed only to growing-finishing pigs and limited to 10% or less of the diet.

- *Low Test Weight Oats*

Research indicates that low test weight oats can be fed effectively to finishing swine. Pigs fed diets containing 33% oats (32 lb / bushel oats) gained the same as pigs fed corn diets but required 5.1% more feed. Therefore, depending on economics, light test weight oats can be used in finishing diets.

Can I use high-moisture corn and frost-damaged soybeans in swine diets?

High-moisture corn (>18% moisture) will have the same feeding value as dry corn (12% moisture) on a dry-matter basis. Since high-moisture corn contains a higher percentage of moisture, a larger percentage of high-moisture corn must be added to a ton of feed to achieve the same nutrient levels achieved with “normal” corn. Also, it must be kept in mind that ensiled or organic acid-treated corn can not be sold at the elevator. It can only be used for livestock feed, so only make what can be fed in a year.

Extruded green soybeans have the same feeding value as extruded mature soybeans. Because of anti-growth factors (e.g., trypsin inhibitors), mature and immature raw soybeans must be heat-treated to inactivate these compounds before feeding them to swine. The only exception is gestating sows, which can use raw soybeans as the sole source of supplemental protein. Factors to consider in determining whether to feed or sell your soybeans (mature or immature) and buy soybean meal are extrusion costs, shrink (8 to 10%), lower protein content of extruded soybeans, an improvement in feed efficiency due to fat addition, and trucking and storage costs.

Can I market my moldy grain through hogs?

Under certain adverse conditions, grains may become moldy. It is not the molds themselves, but rather the mycotoxins the molds produce that cause the negative effects. The main mycotoxins associated with grains are aflatoxin, zearalenone, vomitoxin (DON), fumonisins and ergot. Aflatoxins are found primarily in warmer climates, whereas zearalenone and DON occur in cool, wet conditions. Aflatoxins suppress the immune system, cause a reduction in performance, and at high concentrations (1,000 ppb) death. Zearalenone will cause reproductive problems, infertility, high preweaning death loss and possibly abortions. Though zearalenone’s effects on growing and finishing pigs are minimal, it will cause prepubertal gilts to exhibit red, swollen vulvas and could affect future breeding. Vomitoxin causes feed refusal with little effect on the reproductive herd. However, feed refusal associated with DON will result in a decrease in daily gain. Fumonisins can cause respiratory problems in pigs. Ergot occurs mainly in rye, wheat, barley, and triticale, and results in lactation failure and poor growth. Recommendations are to keep all mycotoxin-contaminated grains out of breeding herd and starting diets, and not to exceed the following rates in other diets:

Aflatoxin	200 ppb in growing-finishing diets
Zearalenone	1 ppm in growing diets and 3 ppm in finishing diets
Vomitoxin (DON)	1 ppm in growing-finishing diets
Fumonisins	5 ppm
Ergot	10% contaminated grain in growing-finishing diets

There are products available that will lessen the impact of aflatoxin (pellet binders, clays, etc.), but there are no products that can be added to swine diets to reduce the detrimental effects of zearalenone, DON, fumonisins and ergot. Drying the grain and adding mold inhibitors will decrease any further mold growth, but they have no effect on the mycotoxins already present.

Should I analyze the feedstuffs I am using?

Byproducts from the food industry such as soybean meal, sunflower meal, dried bakery products, etc. can be excellent feedstuffs for swine. However, since they are byproducts, they are more variable in nutrient content than grains. To ensure proper diet formulation, a nutrient analysis should be conducted on all byproducts used in swine diets. Depending on the quality of soybeans used and the amount of hulls added back, the protein content of 44% CP soybean meal can range from 37 to 45%. Therefore, it is essential to know what kind of product you are working with before using in the diet. Submit a representative sample to an accredited laboratory and have it analyzed for the main nutrient(s) being provided by the byproduct. Consider a mycotoxin screen on grain when drought or wet growing conditions persist, storage problems are suspected, or certain abnormalities are observed in animals.

■ What are proper sampling techniques?

When sampling either individual feedstuffs or processed complete feeds for laboratory analysis, it is essential to get a representative sample. If using a grain trier/probe to obtain samples from a mixer or bagged feed, take at least ten 1/2 pound samples/ton of feed from different locations and combine them into one composite sample for analysis. If sampling from an unloading auger, take at least ten 1/2 pound samples/ton during the entire unloading process, except for the initial and final outputs. Mix the samples, split them in half and send half of the composite sample in for analysis. Store the properly dated and labeled remainder in a freezer for reference. Use the same techniques when taking a grain sample to test for mycotoxins except make sure the sample is sent to the lab in a either a paper or cloth sack. Using plastic bags or metal cans may cause mold growth to occur in transit. For details on interpretation of laboratory results, see the University of Nebraska NebGuide G88-892 (Mixing Quality Pig Feed).

Feed Additives

Feed additives are compounds that may elicit a response independent of contributions to the pig's energy, amino acid, mineral, and(or) vitamin requirements. Typically, these feed additives are added to pig diets in small amounts. In addition, certain nutrients, such as copper and zinc, have been added at pharmacological concentrations (i.e., at high levels the nutrient acts as a drug-see section on nutraceuticals).

■ How are feed additives regulated?

The distribution of all animal feeds entering interstate commerce is regulated by the FDA (Food and Drug Administration). In addition, the FDA monitors the amounts of drugs or feed additives used in the manufacturing of medicated feeds. Specific state laws and regulations may also exist regarding the distribution of feeds and the production of medicated feeds. Besides consulting state and federal regulations, there are two publications that may be helpful:

The Feed Additive Compendium, updated monthly
The Miller Publishing Company
12400 Whitewater Drive, Suite 160
Minnetonka, MN 55343
http://www.feedstuffs.com

Official Publication of the Association of American Feed Control Officials (AAFCO)
Sharon Senesac, AAFCO Assistant Treasurer
P.O. Box 478
Oxford, IN 47971
http://www.aafco.org/

■ How does the FDA describe drug categories used in medicated feeds?

The program that describes the classification of drugs used in medicated animal feeds is commonly known as "Second Generation." This regulatory scheme divides drugs into two major categories:

Category I

Drugs that require no withdrawal at the lowest approved continuous use level for all species.

Category II

Drugs that require withdrawal at the lowest continuous use level for at least one species for which it is approved or is regulated on a "no residue" or "zero tolerance" basis because of carcinogenic concerns.

There are three types of medicated feeds that can incorporate drugs from categories I or II:

Type A Medicated Article

This product is classified as a drug by the FDA and must be classified as a "Medicated Type A Article" on the label. The manufacturer of a Type A article must hold an effective new animal drug application (FD-356) and comply with the current medicated premix and good manufacturing practice regulations.

Type B Product

This product is classified as a medicated feed. The manufacturer of a Type B product from a Type A article containing a Category II drug requires a medicated feed application (FDA - 1900).

Type C Product

Type C products are intended to be used as a complete feed. The manufacture of a Type C product containing a Category II drug manufactured from a Type A article requires a medicated feed application (FDA - 1900).

■ What is a nutraceutical?

Unfortunately, no legal definition for "nutraceutical" exists. It is generally assumed that a nutraceutical is compound between a nutrient and pharmaceutical. Although these compounds/ingredients have a defined nutritional role, pharmacological doses (many fold greater than concentrations needed to elicit a nutritional response) elicit separate effects on pig health or growth. Examples of ingredients considered as nutraceuticals are: zinc oxide, copper sulfate, carnitine, organic chromium, and conjugated linoleic acid.

Because nutraceuticals are labeled as dietary supplements, they are regulated under the Federal Food, Drug, and Cosmetic Act (FFDCA).

Compounds not receiving GRAS (Generally Recognized as Safe) status, (i.e., ingredients that do not have a previous history of use in animal feeds) are of concern. Specifically, ingredients that make **claims** regarding the treatment, prevention, cure, or mitigation of a disease; or affect the structure / function of the body not related to its nutritional role are considered a drug under FFDCA regulations. Although the FDA has placed lower significance on regulating nutraceutical ingredients without drug claims, the FDA's condonation of these ingredients is not indicated.

How do feed additives affect pig performance?

There are many feed additives that have been documented to affect pig performance. Unfortunately, there is not enough space available in this section to cover all these feed additives in detail. The recommended levels for several feed additives are not provided because of either variable usage in the industry or pending status with the FDA. In all cases, if feed additives are to be used, manufacturer and federal guidelines should be followed.

Presented in Table 7 is a brief description of the performance criteria, percent improvement, and use levels for several feed additives. For most of these feed additives, responses have been identified within a range to indicate the variability reported in the literature.

The response to antibiotics varies considerably due to age of the pig, disease level, type and level of antibiotic, season of year, and other environmental factors. Younger pigs show a greater response than older pigs to antibiotics in the feed (Table 7). In most cases, these responses were recorded in "clean" environments (i.e., the overall health status of the pigs and housing conditions were good to excellent). In a "dirty" environment, the response to antibiotics may be greater than shown in Table 7. Antibiotics do not substitute for good management, especially a thorough cleaning of facilities. It may be more economical to correct the underlying problem affecting pig performance than to use antibiotics in the feed.

Some compounds are included in swine diets to avoid feed spoilage and promote feed intake (Table 8). Although improvements in performance are not cited for the feed additives listed in Table 8, circumstances exist where their inclusion in swine diets may increase feed intake and hence gain.

How do I choose a feed additive?

The information in Tables 7 and 8 is presented to allow one to estimate the economic benefit of using some feed additives. When an improvement in feed efficiency is shown, use that to estimate the economic benefit of using the additive. For example, assume feed / gain is improved by an average of 2% when an antibiotic is added to finisher feed. If feed without an antibiotic costs $100 / ton, you can afford to pay about $102 / ton (100 × 1.02) for the medicated feed assuming no benefit from improved daily gain. If a faster growth rate is considered important, factor that in also. When considering a feed additive, give high priority to feed additives that show consistent results from research trials. Also, consult the feed label to learn what the additive is approved for and withdrawal time. Feed additives increase the cost of the diet, thus it is important to reevaluate their use periodically.

How much antibiotic can be added to feed and can antibiotics be mixed together?

Consult the feed label or the *Feed Additive Compendium* for details on the approved level(s) in complete feed and which antibiotics can be fed in combination. If it is not legal to feed certain antibiotics together, consider feeding them in rotation. Moreover, rotating antibiotics may be useful if there is evidence that the effectiveness of the current antibiotic is decreasing. The rotation may be annual or when pigs are switched to different diets.

What are the withdrawal periods for feed additives?

Certain feed additives must be withdrawn from the feed before slaughter to ensure residue-free carcasses. Consult the feed label for withdrawal time for the specific feed additive that is being fed.

Should antibiotics be fed to the breeding herd?

Herds that have experienced problems with conception rates and numbers of pigs born and weaned have often been helped by the addition of therapeutic levels of antibiotics to sow diets. Antibiotics are effective if fed for two weeks before and after breeding and(or) from one week before farrowing to weaning. Results from a regional research study (850 litters) showed an improvement in litter size (.5 pigs / litter) and a slight reduction (negative response) in feed intake during lactation with the addition of chlortetracycline (200 g / ton) from one week before to 15 days after breeding. In the same study, chlortetracycline addition from day 110 of gestation to weaning improved the overall conception rate nearly 6%. In instances where reproductive problems prevail in a herd, a specific diagnosis should be made in consultation with a veterinarian or swine specialist prior to routine inclusion of antibiotics in breeding herd diets. Check the withdrawal time to avoid carcass residues in cull sows.

How do probiotics and antibiotics differ?

Probiotics play a different role than antibiotics in the digestive

Table 7. Performance criteria, percent improvement, and use levels of some common feed additives

Compound	Performance criterion	Growth stage	Improvement, % (average response)	Use level
Antibiotics (for growth promotion)	Daily gain	Starting	4.2 to 136 (15)	Variable[a]
		Growing-finishing	0 to 8.9 (3.6)	
	Feed / gain	Starting	1.7 to 42.7 (6.5)	
		Growing-finishing	-1.8 to 3.8 (2.4)	
Probiotics	Daily gain	Starting	-9 to 11	Variable[a]
		Growing-finishing	-9 to 5	
	Feed / gain	Starting	-2 to 21	
		Growing-finish	-4 to 5	
Copper sulfate	Daily gain	Starting	(24)	125 to 250 ppm
	Feed / gain		(9.7)	
Zinc oxide	Daily gain	Starting	0 to 25	2,500 to 3,000 ppm[c]
	Feed / gain		0 to 8	
Yucca plant extract	Daily gain	Growing-finishing	-1 to 8	57 g / ton
	Feed / gain		0 to 5	
Mycotoxin binders				
HSCA[d]	Daily gain	Growing-finishing	63 to 87[e]	.5%
Clays	Daily gain		71 to 89[e]	.5%
Acidifiers[f]	Daily gain	Starting	0 to 13	3%
	Feed / gain		0 to 14	
Phytase	Daily gain	Growing-finishing	0 to 17[g]	136 to 225 units / lb of compete feed
	Feed / gain		0 to 7[g]	(300 to 500 units / kg of complete feed)
Carnitine	Fat accretion	Starting and growing-finishing	0 to - 40%	
	Daily gain	Starting and growing-finishing	0 to 17%	Variable
	Feed intake		0 to 17%	
	Feed / gain		0 to 17%	
	Litter size	Gestation	0 to 12%	50 ppm
	Birth weight		0 to 12%	
Chromium[h]	Lean gain	Growing-finishing	0 to 6%	Variable
	Litter size	Gestation	0 to 10%	200 ppb
Conjugated linoleic acid	Lean gain	Growing-finishing	0 to 5%	.3%[i]
	Feed / gain		0 to 30%	
	Belly firmness		16 to 50%	
Ractopamine hydrochloride	Daily gain	Finishing	7 to 10%	4.5 to 18 g / ton
	Feed / gain		8 to 13%	
	Carcass lean %		2 to 6%	

[a]Use level will depend on the specific antibiotic.
[b]Use level will depend on the specific probiotic.
[c]Toxicity problems may develop if these levels are provided past about 28 days postweaning.
[d]Hydrated sodium calcium aluminosilicate.
[e]Recovery of lost growth rate when feed is contaminated with aflatoxin.
[f]Fumaric acid.
[g]Response will vary depending on the total level of available phosphorus in the diet.
[h]Organic chromium.
[i]Estimated from the contribution of conjugated linoleic acid from natural ingredients. Not supplied as purified conjugated linoleic acid.

tract. It has been theorized that probiotics increase the population of desirable microorganisms instead of killing or inhibiting undesirable organisms. The most common microorganisms included in probiotic products are Lactobacillus species, which are normal inhabitants of the digestive tract of healthy animals. These bacteria may help remove waste products and inhibit the growth of certain undesirable bacteria. The response to probiotics in pig feed appears to be greater for starting compared to growing-finishing pigs (Table 7). When positive responses have been observed with probiotics it has usually been at weaning.

■ What is carnitine and its effect as a feed additive?

Carnitine is a naturally occurring nutrient and until now was widely thought to be synthesized in sufficient quantities by the pig to meet its requirement. It is involved in the transport of fatty acids into certain parts of the cell so they can be used to produce energy. Carnitine has received limited attention in the growing-finishing phase of production. Although improvements in feed efficiency and leanness have been observed, recent reports have only documented the response in early-weaned pigs (until 35 days postweaning).

There have been interesting findings from experiments examining the role of carnitine in gestation diets. Studies indicate that inclusion of 50 ppm carnitine in gestation diets can improve litter size and(or) pig birth weight. It appears that the improvements in litter size and birth weight may be related to the duration of carnitine supplementation. Nonetheless, the response of both litter size and birth weight have ranged from 0 to 12%.

■ What effect does chromium have as a feed additive?

Chromium (Cr), specifically organic Cr (Cr^{3+}) has been identified as having a role in swine feeding programs. It should be kept in mind that although pigs do have a Cr requirement and Cr is found in pig tissues, forms of elemental Cr, e.g., Cr^{6+} can be toxic. Thus, the role that organic Cr fulfills may be in addition to its classical nutrient role *- see previous section on nutraceuticals.*

Organic Cr (namely, Cr-tripicolinate) has been shown to improve growing-finishing growth performance, and carcass leanness. The results have been variable and some researchers have failed to detect improvements in carcass characteristics or growth performance criteria.

Recently, favorable responses in sow reproductive performance have been observed with the addition of organic Cr to sow gestation and lactation diets. Supplementation of 200 ppb of Cr from Cr-tripicolinate improved sow fertility, number of pigs born and weaned, and reduced sow death loss. Females need to be fed the Cr for about six months before an improvement in reproductive performance can be expected.

■ What is conjugated linoleic acid and its effect as a feed additive?

Conjugated linoleic acid (CLA) is a mixture of polyunsaturated fatty acids. CLA is found primarily in products derived from ruminants. It is produced by the micoflora in the rumen and can be purchased commercially. The most consistent and dramatic effect of including CLA in the diet of growing-finishing pigs has been on belly firmness, and to a lesser degree on feed efficiency and carcass lean percentage (see Table 7).

■ What is ractopamine hydrochloride and its effect as a feed additive?

Ractopamine hydrochloride is a synthetic beta-adrenergic agonist. Ractopamine has a chemical structure similar to dopamine, norepinephrine, and epinephrine, which are naturally occurring substances in animals. These substances, including ractopamine, affect body metabolism via adrenergic receptors on specific tissues. Ractopamine is approved for increased rate of weight gain, improved feed efficiency, and increased carcass leanness in finishing swine fed a complete ration containing at least 16% crude protein from 150 to 240 lb. A feed mill or veterinary feed directive are not required for use of ractopamine. Because ractopamine lowers feed intake 2 to 4% and increases carcass muscle deposition, logic dictates that the dietary amino acid requirement on a percentage basis and possibly on an absolute (total) basis is increased.

Table 8. Function of several feed additives included in swine diets to maintain palatability and(or) feed quality

Compound	Function
Antioxidants[a]	Prohibit fatty acid oxidation and formation of peroxide free radicals. Protect feed sources against the destruction of some vitamins (vitamin A and E). Routine use is recommended.
Mold inhibitors[b]	Increase number of days to mold growth in feed by 5 to 10 days. The greatest benefits are observed where grains being fed are higher than normal in moisture (> 13% moisture).
Flavors	May improve palatability of feed, especially when byproduct ingredients are used. Routine use of flavors is not recommended.

[a]e.g., ethoxyquin, butylated hydroxy tolulene (BHT) and butylated hydroxy anisole (BHA).
[b]e.g., propionic acid and sorbic acid.

Feed Processing

Processing feed is an important step between the nutritionist and the pig. No matter how precisely diets are formulated, pig performance will suffer if the diets are not processed and mixed properly. Critical components of feed preparation include particle size reduction and mixing efficiency.

What average particle size do you recommend for swine diets?

We recommend an average particle size of 650 to 750 microns for all grains except wheat. Finely ground wheat creates palatability problems, thus the optimum particle size for wheat is 850 to 1250 microns for pigs < 130 lb and 1400 to 1800 microns for sows and pigs > 130 lb. Avoid feeding whole kernels of wheat. Process feed so the standard deviation (a measure of particle size variation) is 2 to 2.5.

Reducing ingredient particle size has several advantages. First, it creates more surface area available for digestion resulting in improved feed efficiency. Second, it improves mixing and handling characteristics. The more uniform the feedstuffs are in terms of particle size, the easier they are mixed. A small particle size reduces the amount of segregation of feedstuffs that may occur in bulk bins, augers, and feeders. However, there are several costs associated with smaller particle size. The smaller the particle size the greater the energy and time requirements of processing. Also, there may be increases in dustiness, feed bridging and gastric ulcers.

How do hammermills and roller mills compare?

Particle size usually is reduced by grinding or rolling the grain. Grinding with a hammermill is the most common method. Hammermills have a greater capacity / unit of horsepower, can more easily process different grains and can more easily be adjusted or repaired. However, hammermills require more energy and produce more "fines," and consequentially more dust, than roller mills.

Roller mills use 25 to 30% less energy than hammermills to produce a 700-micron particle, but require more management. Also, because the rolls must be readjusted to accommodate different feedstuffs, roller mills are difficult to use when processing several different grains. There are three essential criteria for producing a 700 to 800-micron particle with a roller mill: (1) a differential drive with one roll moving 50 to 75% faster than the other roll to produce a shearing action instead of a crushing action, (2) the correct number of corrugations / inch to slice the grain and (3) a spiral of 1 to 2" per every 12" of roll length to increase shearing action and decrease fines. Recommendations for corrugations / inch for roller mills and screen sizes for hammermills are shown in Table 9.

To ensure a consistent particle size, both hammermills and roller mills need periodic maintenance. Magnets should be placed in appropriate locations to prevent metal objects from reaching the rolls or screen. Hammers need to be turned or replaced when worn, and rolls need to be regrooved when worn or damaged. Because the screen also helps "cut" the grain, it should be turned or replaced when it becomes dull or develops large holes.

Both types of mills can achieve the desired particle size. Producers need to evaluate such factors as number and types of grain used, time availability, management capabilities, initial investment, and operating costs when determining the best system for their individual operations.

What are the key factors involved in making high quality feed?

Once the grain has been processed to the correct particle size, it must be properly mixed with the other ingredients to achieve the desired diet. Key points in obtaining a good mix are:

- *Weighing the ingredients*

Without weigh scales, the chances of getting the correct number of pounds of each ingredient in the mixer is reduced. Adding too little or too much grain will substantially concentrate or dilute the amounts of other ingredients in the diet. Volumetric systems can be satisfactory but they must be recalibrated frequently. However, because of differences in bulk density of different grains and batches of soybean meal, basemixes and premixes, weigh scales are essential in ensuring proper diet preparation.

Table 9. Hammermill and roller mill recommendations to achieve a 700-micron average particle size

	Hammermill	Roller mill
Grain	Screen size, inches	Corrugations/inch
Barley	1/8	10 to 12
Corn	3/16	8 to 10
Oats	1/8	10 to 12
Milo	1/8	12 to 14
Wheat	[a]	10 to 12

[a]To avoid palatability problems, wheat should be coarsely ground or rolled to achieve the proper particle size. See text for details.

- *Mixing times*

  Run vertical screw mixers at the proper speed for at least 15 minutes after the last ingredient is added. Horizontal and drum mixers should run for 5 to 10 minutes after the addition of the last ingredient. Older, worn mixers need to be run longer.

- *Sequencing and premixing*

  Add at least half of the grain or all of the supplemental protein before adding any other ingredients. Also, if an ingredient is added at less than 2% of the total batch (< 40 lb in a ton batch) in a vertical screw mixer or less than 1% in a horizontal mixer, it needs to be premixed to a larger volume to ensure proper mixing.

What about other methods of processing?

Alternate methods of processing feedstuffs and feed include extrusion, roasting, pelleting, steam flaking, expanding and micronizing. Extrusion and roasting are most commonly used in the heat treatment of soybeans to inactivate antinutritional factors found in raw soybeans. Extrusion involves the use of heat, pressure, and possibly steam on ingredients or feeds. Roasting is a simpler process, but there is a greater potential for over- and under-heating. Expanding is similar to extrusion, and the results have been mixed at best with swine diets, especially when economics are considered. Steam flaking and micronizing are processing methods that usually do not increase performance enough to justify the cost of processing.

Pelleting swine diets is becoming more popular. This is especially true in starter pig diets because pelleting prevents bridging in feeders when using diets high in milk products. Pelleting corn or milo-based diets for growing and finishing pigs results in a 5 to 8% improvement in feed efficiency and increases daily gain by 3 to 6%. Pelleting barley or oat-based diets improves feed efficiency by 7 to 10% and daily gain by 3 to 6%. The improvement in feed efficiency is due to a decrease in feed wastage and improved nutrient use. However, the decision to pellet diets other than in the starting phase should to be based on economics. In general, the more expensive the diet the more economical it is to offer as a pellet.

When determining the economic benefit of any form of processing, the following formula can be used:

$$\frac{\text{New diet cost - old diet cost x 100}}{\text{Old diet cost}}$$

< or = % improvement in feed efficiency needed to offset added diet cost

For example, assume pelleting will increase the diet cost from $110/ton to $125/ton. Therefore, a 13.6% improvement in feed efficiency is needed to cover the pelleting cost. Any improvement in feed efficiency above that will be profit.

$$\frac{\$125 - \$110}{\$110} \times 100 = 13.6\% \text{ improvement in feed efficiency}$$

Water

Water is one of the most important components of a feeding program for swine. Vital to all body functions, water accounts for as much as 80% of body weight in pigs at birth and declines to about 50% in market swine.

How much water does a pig consume?

Refer to Table 10 for estimated water needs of various classes of swine. In general, a pig will consume 1/4 to 1/3 gallon of water for every pound of dry feed. The water requirements are variable, with the need for water increasing when a pig has diarrhea or experiences warm or hot environmental conditions. Diets high in salt or protein or other ingredients whose byproducts of digestion and metabolism are excreted via the kidney also increase water needs.

Table 10. Water consumption by pigs

Class	Water consumption, gallon/pig/day
Gestating sow	2 to 3
Lactating sow	4 to 5
Starting pig (13 to 45 lb)	.5 to 1
Growing pig (45 to 130 lb)	1
Finishing pig (130 to 250 lb)	1.5 to 2

Lactating sows must have unlimited access to water if they are to produce milk adequately. Suckling pigs older than 10 to 14 days of age need water in addition to that in milk for optimum performance.

With typical nipple drinking devices, the rate of delivery (cups/minute) has little effect on performance as long as a minimal delivery rate is achieved with the device. Pigs generally make up for reduced delivery rates by spending more time at the drinking device. Suggested minimum delivery rates for nipple drinking devices are:

starting pigs — 1 to 1.5 cups/minute
growing-finishing pigs — 2 to 3 cups/minute
sows and boars — 3 to 4 cups/minute

For all classes of swine that are housed in pens, we recommend that at least one nipple drinker device be provided for every 15 pigs in the social group, with a minimum of 2 devices per group. We recommend one nipple drinker device for every 10 pigs in the nursery.

Recent research suggests that if water waste is a concern, the use of wet/dry feeders or bowl drinkers may result in which the nipple drinker is incorporated in the feed bowl of the feeder as the sole source of water may result in up to a 40% reduction in slurry volume. Newer designs of drinking devices may also reduce water wastage when compared to traditional nipple drinking devices. Consideration of the need for wasted water for proper functioning of manure transfer and storage devices is a consideration in drinker device selection.

What about water quality?

Water that meets standards for human consumption is ideal. Most problems with water quality are related to bacterial contamination, either in the well or water delivery system. A laboratory result equal to or less than 1 coliform per 100 mL is considered acceptable for all classes of swine. Levels higher than 5 bacteria forming colonies per 100 mL are cause for immediate concern and remedial action.

Water containing elevated levels of sulfates (so called stinky water) will cause a slight to moderate diarrhea with a characteristic black color in the feces. Water containing up to 3,000 ppm sulfate or 5,000 ppm total dissolved solids (TDS) can be consumed safely by swine after a period of adaptation.

Many laboratories report electrical conductivity as an estimator of TDS. Although the constant in the formula varies somewhat depending on the sulfate content of the water in question, a general estimate of TDS is:

$$TDS = K / .75$$

where: TDS = Total Dissolved Solids in ppm
K = electrical conductivity in microomhmos
.75 = constant

Water containing up to 100 ppm NO_3-N (nitrate-nitrogen) or 440 ppm NO_3 (nitrate) is considered safe for all classes of swine. Recent research results suggest that water containing up to 450 ppm NO_3-N or 1,980 ppm NO_3 will not cause adverse reactions in growing-finishing pigs.

Water normally contains minerals that are added to swine diets (e.g. calcium or sodium). However, minerals from a water source should not substitute for quantities recommended in the feed.

Do you recommend using water sweeteners or water acidifiers?

No. Water sweeteners and acidifiers have been ineffective in routinely enhancing water intake and improving the performance of starting pigs.

Feed Intake

Feed intake is used synonymously with feed disappearance from feeders or storage bins. Feed disappearance includes feed that is eaten and feed that is wasted or spilled and probably overestimates actual feed consumed. Certain processing methods (e.g., pelleting), feeder design and management practices reduce feed disappearance because feed wastage is reduced, but they may have little effect on feed intake. Other practices, such as liquid or paste feeding, may produce a real increase in feed consumption.

Why is feed intake important?

Growing pigs and lactating sows generally are given free or ad libitum access to feed, whereas boars and non-lactating gilts or sows are limit-fed. It is assumed that when swine are not limit-fed, they will consume feed in quantities sufficient for maximum production. A number of factors may alter feed consumption, resulting in greater or lesser amounts of feed consumed than expected. As feed consumption varies, so does the daily supply of nutrients. Nutrient intake can be standardized by adjusting nutrient levels in a diet inversely with changes in feed intake. However, altering nutrient density is not advisable when energy is the limiting factor.

What factors affect feed intake?

Pigs consume feed in meals. As pigs advance from weaning to slaughter weight, meal frequency decreases from about 12 to five meals per day. Factors that alter daily feed consumption do so by either reducing or prolonging the duration of individual meals as opposed to affecting meal frequency.

• *Energy density*

The amount of energy consumed depends on the amount of feed eaten and the amount of energy per pound of feed. Pigs typically eat until their energy requirements are satisfied. Adding fat to a diet reduces feed intake because energy density increases. Fibrous feeds (e.g., barley, alfalfa and oats) dilute energy density and increase bulk when added to a diet. As dietary fiber increases, feed intake increases until gastrointestinal capacity is reached, causing intake to reach a plateau. This plateau may occur before energy needs are satisfied. Energy dilution is of particular concern for pigs weighing less than 80 lb and for most lactating sows. This is because energy intake tends to be limiting for maximum performance in these classes of swine, even when they are fed low-fiber diets.

• *Temperature*

Consistent exposure to environmental temperatures above or below the pig's thermoneutral zone affects feed consumption. As environmental temperature increases from comfortable to moderately stressful, feed consumption declines proportionally. However, extreme heat stress drastically reduces feed consumption. Susceptibility to heat stress increases as body weight increases. Conversely, feed consumption increases as environmental temperature is reduced within a moderate range. Finishing pigs in a cold environment eat more because their maintenance energy requirement is increased to maintain body temperature. Growth rate may not be affected, but poorer feed efficiency results. However, severely cold-stressed pigs may not grow because they can not consume sufficient amounts of energy above their maintenance requirement. The effects of cold weather are less detrimental as body weight increases. Limit-fed swine are an exception because they can not voluntarily adjust energy intake. The manager must make these adjustments and increase feeding level according to severity of the cold stress.

• *Gender*

A summary of eight studies below shows that feed consumption is affected by gender. Although differences in feed intake between barrows and gilts may occur at lighter weights, they probably are not of practical importance until pigs weigh about 80 lb or more. After 80 lb, barrows will consume more feed than gilts. It appears boars consume less feed than gilts during the grower phase, but they have similar feed intakes in the finisher phase.

Relative effect of sex on feed intake (boar = 100)

Phase	Boar	Barrow	Gilt
Grower (45 to 130 lb)	100	108	105
Finisher (130 to 250 lb)	100	114	101

• *Genetics*

Genetics play an important role in determining feed intake levels in swine. Genetic lines selected primarily for improved feed efficiency or for leanness may also be indirectly selected for low feed consumption. Thus, pigs from different genetic lines may consume different amounts when given free access to feed. However, it is not possible to make general statements about differences in feed intake among genetic lines. For example, some high lean gain genotypes were thought to have reduced feed intake. This might seem logical because carcass leanness is increased by restricting feed intake. However, there is evidence that pigs with high lean growth potential and those with medium or low lean growth eat similar amounts of feed. Therefore, feed intake patterns of genetic lines should be determined from previous records and daily consumption should not be used to classify pigs according to lean growth type.

• *Weaning*

Severely restricted consumption at weaning is a common occurrence and the principal cause of postweaning lag. This problem has been addressed in our nutrient recommendations (Table 11), and further adjustments in nutrient density are not needed. The starter 1 (or transition) diet should contain highly palatable and digestible ingredients (see example diets in Table 19) to encourage pigs to begin eating as quickly as possible.

• *Amino acids*

Pigs fed diets that are not correctly balanced for amino acids may exhibit reduced feed intake. The severity varies depending on the levels and characteristics of the amino acids involved. Formulation errors that allow some alternative feed ingredients or crystalline amino acids to be used incorrectly cause these problems. Such errors can be avoided by using our lysine, tryptophan, threonine and methionine recommendations when formulating diets.

• *Gestation feeding*

Sows that are overfed during gestation exhibit reduced feed consumption during lactation. The excess energy consumed during gestation is stored as fat and used during lactation, resulting in greater lactation weight loss. Sows fed our recommended amounts during gestation (adjusted for environment as necessary) gain less weight during gestation and lose less weight during lactation. They obtain the additional energy needed during lactation by eating more feed. The total amount of feed eaten for the combined gestation and lactation periods may be similar whether sows are overfed or fed correctly during gestation. However, sows that are too fat at farrowing may cause management difficulties and are more likely to crush their pigs.

• *Feed acceptability*

Pigs may reduce consumption or refuse to eat when the diet contains unpalatable or objectionable ingredients. This may be noticed first among limit-fed swine, because they eat well defined meals. The effects on pigs given free access to feed are less obvious and may not be noticed until performance losses occur. Certain odors, textures, flavors and tastes (especially bitter) may contribute to reduced feed intake. Some ingredients may reduce palatability when large quantities are used in the diet. Small quantities of mold and(or) mycotoxin contaminated feeds may dramatically reduce feed intake. To avoid these problems, do not use poor quality ingredients in swine diets.

Stale feed may be considered unacceptable to swine that are hesitant to eat because of stress. Lactating sows, newly weaned pigs and pigs recovering from disease can be encouraged to eat by providing fresh feed several times per day. Spilled or wasted feed left on the ground or floor of a pig pen for more than 30 minutes probably will not be eaten.

• *Other factors*

Crowding, limited feeder space and disease often reduce feed consumption. These problems should be identified and treated by making the appropriate changes in management or facilities, rather than by making diet changes. Further, altering nutrient density will not overcome performance reductions resulting from crowding. Feeder design and management affect feed consumption somewhat, but play a greater role in managing feed wastage. Assuming adequate feed access is provided, feeder design usually is of less importance than adjustments to reduce or minimize feed wastage. One exception may be sows during lactation, if the feeder design limits a sow's access to feed.

Health

When pigs are exposed to antigens (substances foreign to the body), there may be fewer nutrients available for normal growth. Management procedures such as segregated early weaning (SEW) or medicated early weaning (MEW) are being employed to reduce or eliminate the pig's exposure to antigens. Presumably because of an improved health status, SEW or MEW pigs consume more feed, grow faster and require less feed per unit of gain from weaning to slaughter weight than do pigs weaned after about 21 days of age and kept in the vicinity of older pigs.

Information on the relationship between pig health and nutrient requirements is being generated. Preliminary research indicates that amino acid requirements (expressed as amount/day) are increased in high-health pigs, because of their greater capacity for lean growth. Starting pigs derived from SEW or MEW programs should not require diets containing higher concentrations of nutrients than those listed in Table 11. Their greater nutrient demand should be met by a higher feed consumption. The lean gain classifications for growing-finishing pigs in this publication are a function of both the pig's genetics and the environment. Health status is one of the environmental constraints on lean gain. Therefore, based on the available evidence, we believe categorizing growing-finishing pigs as high, medium or low lean gain and feeding them as described in this publication accounts for the impact of health status on amino acid requirements.

Nutrient Recommendations

We believe the nutrient recommendations in Tables 11, 12, 13, 14, 15 and 16 will result in a "best-cost" feeding strategy for most producers the majority of the time. However, certain conditions (i.e., specific genetic populations, economic, nutrient availability, nutrient profile and nutrient interactions) may require significant deviations from the recommendations presented. Also, the current debate surrounding the environmental consequences of nitrogen and phosphorus excretion was considered in the development of amino acid and phosphorus recommendations.

Although crude protein values still appear on feed labels and in some feeding recommendations, we did not list dietary protein recommendations because pigs do not require protein in their diet. Instead they require amino acids, which are found in protein. The recommended levels for the most critical amino acids are given in Tables 11, 12, 13, 14 and 15. Lysine is the first limiting amino acid in grain-soybean meal-based diets. In these diets, there is a strong relationship between the protein and the lysine level of the diet. For example, a corn or milo soybean meal-based diet containing .95% lysine will contain about 18% protein. A diet with .80% lysine will contain about 16% protein and a diet with .65% lysine has about 14% protein.

The recommendations for tryptophan, threonine, methionine and methionine+cystine were derived from an optimum pattern or ratio among amino acids that we established (Table 17). We assumed that the pattern of amino acids required changes throughout the growth stages, except for tryptophan and methionine. Lysine is needed in a much larger proportion for the synthesis of new tissue than for maintenance. Thus, for example, the recommended amount of threonine in the diet as a percent of lysine increases from 64% in the starting phase to 68% in the finishing phase.

The ranges presented for trace mineral and vitamin additions offer feed manufacturers greater flexibility, which often results in cost savings in preparing custom products from our nutrient recommendations. The minimum values generally represent the quantity recommended by the National Research Council (1998). The upper values do not represent the maximum safe or tolerance levels, but instead a reference point above which further additions will not likely improve performance. We do not necessarily recommend supplying minimum or maximum levels on a routine basis. An example of appropriate trace mineral and vitamin additions to pig feed is shown in Table 16.

The recommendations reflect differences in nutrient requirements for pigs according to their stage of production, sex, lean growth rate and milk production. We assumed the same feed intake for pigs with different lean growth rates, an assumption that is not always true. We also assumed pigs are housed under thermoneutral

Table 11. Nutrient recommendations for growing swine (as-fed basis)[a, b]

Type of diet	Starter 1 /transition[c]	Starter 2	Starter 3	Grower 1	Grower 2	Finisher 1	Finisher 2
Body wt, lb	**8 to 13**	**13 to 25**	**25 to 45**	**45 to 80**	**80 to 130**	**130 to 190**	**190 to 250**
Expected feed intake, lb/day[d]	**.55**	**1.2**	**2.0**	**3.3**	**4.6**	**5.8**	**6.9**
	% of Diet						
Lysine, total	1.55	1.35	1.20	1.00	.85	.70	.55
Lysine, **digestible**	1.29	1.12	.99	.82	.68	.55	.41
Tryptophan	.28	.24	.22	.18	.15	.13	.10
Threonine	.99	.86	.77	.66	.56	.48	.37
Methionine	.40	.35	.31	.26	.22	.18	.14
Methionine+cystine	.88	.77	.68	.57	.49	.41	.32
Calcium	.90	.85	.75	.70	.60	.55	.50
Phosphorus, total	.77	.67	.62	.58	.51	.47	.43
Phosphorus, **available**	.56	.44	.34	.29	.22	.19	.16
	Calculated Daily Intake, g						
Lysine, total	3.9	7.4	10.9	15.0	17.8	18.4	17.2
Lysine, **digestible**	3.2	6.1	9.0	12.2	14.2	14.5	13.0
Tryptophan	.7	1.3	2.0	2.7	3.2	3.3	3.1
Threonine	2.5	4.7	7.0	9.9	11.7	12.5	11.7
Methionine	1.0	1.9	2.8	3.9	4.6	4.8	4.5
Methionine+cystine	2.2	4.2	6.2	8.6	10.1	10.7	10.0
Calcium	2.3	4.6	6.8	10.5	12.5	14.5	15.7
Phosphorus, total	1.9	3.7	5.6	8.7	10.7	12.4	13.5
Phosphorus, **available**	1.4	2.4	3.1	4.3	4.6	5.0	5.0
	Additions						
Minerals							
Salt, %[e]	0 to .4	0 to .4	.25 to .4	.25 to .4	.25 to .4	.25 to .4	.25 to .4
Copper, ppm	6 to 15	6 to 15	5 to 15	4 to 15	4 to 15	3 to 15	3 to 15
Iodine, ppm	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5
Iron, ppm	100 to 150	90 to 150	80 to 150	70 to 150	60 to 150	50 to 150	40 to 150
Manganese, ppm	4 to 30	3 to 30	3 to 30	3 to 30	2 to 30	2 to 30	2 to 30
Selenium, ppm[f]	.3	.3	.3	.3	.3	.3	.3
Zinc, ppm	100 to 150	90 to 150	80 to 150	70 to 150	60 to 150	50 to 150	50 to 150
Vitamins							
Vitamin A, IU / lb	1000 to 4000	900 to 4000	800 to 4000	700 to 4000	650 to 4000	600 to 4000	600 to 4000
Vitamin D_3, IU / lb	100 to 400	90 to 400	80 to 400	70 to 400	70 to 400	70 to 400	70 to 400
Vitamin E, IU / lb	7.5 to 30	6 to 30	5 to 30	5 to 20	5 to 20	5 to 20	5 to 20
Vitamin K, mg / lb[g]	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3
Riboflavin, mg / lb	2 to 10	2 to 10	2 to 10	2 to 10	1 to 10	1 to 10	1 to 10
Niacin, mg / lb	10 to 50	7 to 50	6 to 50	5 to 50	4 to 50	4 to 50	3 to 50
Pantothenic acid, mg / lb	6 to 25	5 to 25	4 to 25	4 to 25	4 to 25	4 to 25	3 to 25
Choline, mg / lb[h]	0 to 100	0 to 100	0 to 100	0 to 100	0 to 100	0 to 100	0 to 100
Biotin, mg / lb	0	0	0	0	0	0	0
Vitamin B_{12}, mg / lb	.01 to .02	.01 to .02	.01 to .02	.005 to .02	.003 to .02	.003 to .02	.002 to .02
Folic acid, mg / lb	0	0	0	0	0	0	0

[a]Assumes a mixture of medium lean gain barrows and gilts (.55 to .70 lb of fat-free lean / day from 45 to 250 lb). All diets are full-fed under thermoneutral conditions.
[b]Digestible and available nutrient levels are calculations based on a corn-soybean meal diet.
[c]Provide a total of 4 lb / pig (at least 3 lb after weaning) to pigs > 13 lb at weaning, but < 28 days of age.
[d]Average dietary ME density is 1.5 Mcal / lb.
[e]Adjust salt additions according to quantity of dried whey and plasma proteins included in the diet. Dietary sodium levels > 3000 ppm are not likely to improve performance.
[f]Maximum legal addition is .3 ppm.
[g]Menadione activity.
[h]Soybean meal is an excellent source of choline. Starting diets containing less than 100 lb soybean meal / ton should contain about 50 mg / lb of added choline.

Table 12. Recommended dietary levels (%) of amino acids for HIGH, MEDIUM, and LOW lean gain swine (as-fed basis)[a, b, c]

Type of diet	Grower 1		Grower 2		Finisher 1		Finisher 2	
Body wt, lb	45 to 80		80 to 130		130 to 190		190 to 250	
Sex[d]	B	G	B	G	B	G	B	G
Expected feed intake, lb/day[e]	3.3	3.3	4.7	4.5	6.2	5.5	7.2	6.6
High Lean Gain[f]								
Lysine, total	1.10	1.10	.97	1.01	.77	.87	.62	.68
Lysine, **digestible**	.90	.90	.78	.82	.61	.70	.49	.54
Tryptophan	.20	.20	.17	.18	.14	.16	.11	.12
Threonine	.73	.73	.64	.67	.52	.59	.42	.46
Methionine	.29	.29	.25	.26	.20	.23	.16	.18
Methionine+cystine	.63	.63	.55	.58	.45	.50	.36	.39
Medium Lean Gain[g]								
Lysine, total	1.00	1.00	.83	.87	.65	.74	.53	.57
Lysine, **digestible**	.82	.82	.67	.70	.52	.59	.41	.44
Tryptophan	.18	.18	.15	.16	.12	.13	.09	.10
Threonine	.66	.66	.55	.58	.44	.50	.36	.39
Methionine	.26	.26	.22	.23	.17	.19	.14	.15
Methionine+cystine	.57	.57	.48	.50	.38	.43	.31	.33
Low Lean Gain[h]								
Lysine, total	.80	.80	.69	.72	.55	.62	.45	.49
Lysine, **digestible**	.64	.64	.54	.57	.42	.48	.33	.37
Tryptophan	.14	.14	.12	.13	.10	.11	.08	.09
Threonine	.53	.53	.45	.47	.37	.42	.31	.34
Methionine	.21	.21	.18	.19	.14	.16	.12	.13
Methionine+cystine	.46	.46	.39	.41	.32	.36	.26	.29

[a]All diets are full fed under thermoneutral conditions.
[b]Digestible nutrient levels are calculations based on a corn-soybean meal diet.
[c]Sufficient data are not available to indicate that requirements for other nutrients are different from those in Table 11 for animals of these weights.
[d]B=barrows and G=gilts.
[e]Average dietary ME density is 1.5 Mcal / lb.
[f]> .70 lb of fat-free lean / day from 45 to 250 lb.
[g].55 to .70 lb of fat-free lean / day from 45 to 250 lb.
[h]< .55 lb of fat-free lean / day from 45 to 250 lb.

conditions, which is also not always true.

When is it appropriate to alter dietary nutrient density according to feed intake?

• *Starting and growing pigs*

The daily amino acid and mineral recommendations for starting and growing pigs (8 to 130 lb) were designed for pigs consuming the quantities of feed indicated at the top of Tables 11, 12, 13, and 15. When these pigs consume less feed than indicated, we do not recommend increasing amino acid and mineral concentrations in an attempt to maintain our calculated daily nutrient intakes. In other words, do not attempt to formulate diets for starting and growing pigs for a specific intake of nutrients.

The relationship between lean gain and energy intake is linear for pigs within this weight range. Changes in energy intake directly affect lean gain, which may alter amino acid requirements. If energy is limiting because feed consumption is lower than expected, lean gain also will be lower. In this case, providing more amino acids by increasing the percentages in the diet probably will not improve pig performance. An exception might be when fat is added to the diet and feed intake is reduced because less feed is required to meet the pig's energy requirement. Therefore, increasing the percentages of amino acids and minerals to maintain a constant nutrient:calorie ratio is recommended. However, newly weaned pigs (< 28 days of age) do not respond to changes in energy density of the diet. Nutrient levels should not be adjusted in these diets until pigs have been weaned for about two weeks.

Higher than expected consumption during the starting and growing phases is not a problem and our recommended percentages of amino acids and minerals should be maintained. This will result in daily nutrient intakes that exceed our calculated levels. Energy intake will also be greater than expected, so the additional amino acids and minerals will be needed to support increased lean gain.

• *Finishing pigs*

At times, it may be advisable to increase the percentages of amino

Table 13. Calculated daily intake (g) of amino acids for HIGH, MEDIUM, and LOW lean gain swine (as-fed basis)[a, b, c]

Type of diet	Grower 1		Grower 2		Finisher 1		Finisher 2	
Body wt, lb	45 to 80		80 to 130		130 to 190		190 to 250	
Sex[d]	B	G	B	G	B	G	B	G
Expected feed intake, lb/day[e]	3.3	3.3	4.7	4.5	6.2	5.5	7.2	6.6
High Lean Gain[f]								
Lysine, total	16.5	16.5	20.8	20.7	21.7	21.7	20.4	20.4
Lysine, **digestible**	13.5	13.5	16.7	16.7	17.2	17.2	15.9	15.9
Tryptophan	3.0	3.0	3.7	3.7	3.9	3.9	3.7	3.7
Threonine	10.9	10.9	13.7	13.7	14.8	14.8	13.9	13.9
Methionine	4.3	4.3	5.4	5.4	5.6	5.6	5.3	5.3
Methionine+cystine	9.4	9.4	11.8	11.8	12.6	12.6	11.8	11.8
Medium Lean Gain[g]								
Lysine, total	15.0	15.0	17.8	17.8	18.4	18.4	17.2	17.2
Lysine, **digestible**	12.2	12.2	14.2	14.2	14.5	14.5	13.0	13.0
Tryptophan	2.7	2.7	3.2	3.2	3.3	3.3	3.1	3.1
Threonine	9.9	9.9	11.7	11.7	12.5	12.5	11.7	11.7
Methionine	3.9	3.9	4.6	4.6	4.8	4.8	4.5	4.5
Methionine+cystine	8.6	8.6	10.1	10.1	10.7	10.7	10.0	10.0
Low Lean Gain[h]								
Lysine, total	12.0	12.0	14.7	14.7	15.5	15.5	14.8	14.8
Lysine, **digestible**	9.6	9.6	11.5	11.5	11.8	11.8	10.9	10.9
Tryptophan	2.2	2.2	2.6	2.6	2.8	2.8	2.7	2.7
Threonine	7.9	7.9	9.7	9.7	10.5	10.5	10.1	10.1
Methionine	3.1	3.1	3.8	3.8	4.0	4.0	3.8	3.8
Methionine+cystine	6.8	6.8	8.4	8.4	9.0	9.0	8.6	8.6

[a]All diets are full fed under thermoneutral conditions.
[b]Digestible nutrient levels are calculations based on a corn-soybean meal diet.
[c]Sufficient data are not available to indicate that requirements for other nutrients are different from those in Table 11 for animals of these weights.
[d]B=barrows and G=gilts.
[e]Average dietary ME density is 1.5 Mcal / lb.
[f]> .70 lb of fat-free lean / day from 45 to 250 lb.
[g].55 to .70 lb of fat-free lean / day from 45 to 250 lb.
[h]< .55 lb of fat-free lean / day from 45 to 250 lb.

acids and minerals in the diet of finishing pigs (> 130 lb) consuming less feed than indicated in Tables 11, 12, 13 and 15. In other words, it may be appropriate to formulate finishing diets to a specific intake of nutrients. Compared with younger pigs, energy intake and lean gain are not as closely related during this stage. Moderate reductions in energy intake are less likely to affect lean growth rate. Therefore, if actual feed intake is within 90% of listed levels, our calculated daily amino acid and mineral recommendations should be maintained by increasing the density of these nutrients in the diet.

For example, assume 190 to 250 lb finishing pigs were fed a diet containing .55% lysine and their feed intake was 6.4 lb or 2905 g / day. Therefore, the pigs' daily lysine intake was 16.0 g / day (2905 x .055) which is below that recommended in Table 11. The pigs' lysine intake was reduced because they were consuming about 7% less feed than expected (Table 11). Because the reduction in feed intake is within 10% of the expected amount shown in Table 11, the diet can be reformulated so the pigs consume the recommended amount of lysine (17.2g / day).

$$\frac{17.2 \text{ g lysine / day}}{2905 \text{ g feed / day}} = .0059$$

$$.0059 \times 100 = .59\% \text{ lysine}$$

Similarly, nutrient density should be increased to maintain a constant nutrient:calorie ratio when fat is added to the diet. However, the percentages of amino acids and minerals in the diet should not be adjusted when severe reductions in feed consumption (> 10%) occur. Examples of when not to increase nutrient density include (1) heat stress resulting from continued exposure to temperatures in excess of 90°F and (2) crowding.

During the finishing stages, increases in feed intake may occur during periods when additional energy is needed for maintenance (such as during cold weather). Additional amino acids and minerals are not needed. Thus, we recommend that producers reduce the percentages of amino acids and minerals in the diet to maintain our calculated daily intakes of these nutrients. This recommendation only applies when temperatures remain cold for a prolonged

Table 14. Nutrient recommendations for adult breeding swine (as-fed basis)[a, b]

Type of diet	Developing gilt	Gestation	Lactation				Breeding Boar
Body wt, lb	230 lb to flushing						
21-day litter weight			< 120 lb		> 120 lb		
Expected feed intake, lb/day[c]	6.0[d]	4.0[d]	10.5	12.0	12.0	14.0	5.5[d]
	% of Diet						
Lysine, total	.70	.55	.90	.85	1.05	1.00	.70
Lysine, **digestible**	.54	.42	.73	.69	.87	.82	.54
Tryptophan	.13	.10	.16	.15	.19	.18	.13
Threonine	.48	.45	.58	.55	.67	.64	.57
Methionine	.18	.14	.23	.21	.26	.25	.18
Methionine+cystine	.41	.37	.43	.41	.51	.48	.47
Calcium	.75	.90	.90	.90	.90	.90	.75
Phosphorus. total	.65	.75	.75	.75	.75	.75	.65
Phosphorus, **available**	.40	.49	.49	.49	.49	.49	.40
	Calculated Daily Intake, g						
Lysine, total	19.1	10.0	43.0	46.5	57.4	63.5	17.5
Lysine, **digestible**	14.7	7.7	34.8	37.6	47.1	52.1	13.4
Tryptophan	3.4	1.9	7.7	8.4	10.3	11.4	3.3
Threonine	13.0	8.1	27.5	29.8	36.7	40.6	14.2
Methionine	5.0	2.6	10.8	11.6	14.4	15.9	4.6
Methionine+cystine	11.1	6.7	20.6	22.3	27.6	30.5	11.7
Calcium	20.4	16.3	42.9	49.0	49.0	57.2	18.7
Phosphorus, total	17.7	13.5	35.6	41.0	41.0	47.5	16.2
Phosphorus, **available**	11.0	8.9	23.5	26.5	26.5	31.0	10.0
	Additions						
Minerals							
Salt, %	.4 to .6	.4 to .6	.4 to .6	.4 to .6	.4 to .6	.4 to .6	.4 to .6
Copper, ppm	5 to 15	5 to 15	5 to 15	5 to 15	5 to 15	5 to 15	5 to 15
Iodine, ppm	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5	.15 to .5
Iron, ppm	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150
Manganese, ppm	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40
Selenium, ppm[e]	.3	.3	.3	.3	.3	.3	.3
Zinc, ppm	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150	80 to 150
Vitamins							
Vitamin A, IU/lb	2000 to 5000	2000 to 5000	2000 to 5000	2000 to 5000	2000 to 5000	2000 to 5000	2000 to 5000
Vitamin D_3, IU/lb	90 to 500	90 to 500	90 to 500	90 to 500	90 to 500	90 to 500	90 to 500
Vitamin E, IU/lb	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40	20 to 40
Vitamin K, mg/lb[f]	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3	1 to 3
Riboflavin, mg/lb	2 to 10	2 to 10	2 to 10	2 to 10	2 to 10	2 to 10	2 to 10
Niacin, mg/lb	5 to 50	5 to 50	5 to 50	5 to 50	5 to 50	5 to 50	5 to 50
Pantothenic acid, mg/lb	6 to 25	6 to 25	6 to 25	6 to 25	6 to 25	6 to 25	6 to 25
Choline, mg/lb	250 to 500	250 to 500	250 to 500	250 to 500	250 to 500	250 to 500	0 to 500
Biotin, mg/lb	0 to .2	0 to .2	0 to .2	0 to .2	0 to .2	0 to .2	0 to .2
Vitamin B_{12}, mg/lb	.007 to .02	.007 to .02	.007 to .02	.007 to .02	.007 to .02	.007 to .02	.007 to .02
Folic acid, mg/lb	.6 to 1.8	.6 to 1.8	.6 to 1.8	.6 to 1.8	.6 to 1.8	.6 to 1.8	.6 to 1.8

[a]All diets are full fed (except developing gilt, gestation and breeding boar diets) under thermoneutral conditions.
[b]Dietary and available nutrient levels are calculations based on a corn-soybean meal diet.
[c]Average dietary ME density is 1.5 Mcal/lb.
[d]Adjust to achieve a desired body condition or weight gain.
[e]Maximum legal addition is .3 ppm.
[f]Menadione activity.

period. Temperatures should be monitored where the pig is (same height and location). Remember that air movement, bedding, humidity and group size affect how pigs perceive temperature.

Including fibrous ingredients in the diet will increase feed consumption. Nutrient density can be reduced in these diets to maintain a constant nutrient:calorie ratio. As temperatures fall below the lower critical temperature, consumption of fibrous diets may not increase to the same extent as for low-fiber diets. This is because (1) feed intake has already increased in response to the reduced energy density and (2) consumption of bulky diets is limited by gastrointestinal capacity. Therefore, reductions in nutrient density other than for energy density are not recommended.

- *Adult breeding swine*

Breeding boars or gestating sows and gilts fed amounts different from those recommended in Table 14 should receive our calculated daily nutrient intakes. Thus, the percentages of amino acids and minerals should be increased for lower feeding levels and decreased for higher feeding levels. This is particularly important for boars because inadequate amino acid intake can depress libido. If diets designed for higher feeding levels are formulated on a total phosphorus basis, check to see if the daily available phosphorus recommendation in Table 14 is met. It is possible to meet our total phosphorus recommendation but not the available phosphorus recommendation with diets containing large amounts of corn or milo. Lactation diets should not be adjusted when sows consume more feed than listed in Table 14. Adding fat to lactation diets will reduce feed intake slightly. The nutrient:calorie ratio should be held constant in lactation diets containing fat by increasing the percentages of amino acids and minerals.

Practical Applications and Outcomes

The recommendations and concepts presented in this publication are intended to help pork producers apply appropriate nutrition-based technologies. These technologies are designed so that nutrition does not limit production potential and profitability in most situations. However, pigs must be capable of responding to improved nutrition. Weaknesses in the operation such as crowding, poor sanitation, inadequate ventilation, chronic disease, and lack of proper temperature control will limit the response to nutrition. Optimum nutrition can not substitute for good management practices but must be used to complement good management.

Table 15. Nutrient recommendations for developing breeding swine (as-fed basis)[a, b, c]

Type of diet	Terminal-line developing boar				Maternal-line developing gilt			
Body wt, lb	**45 to 80**	**80 to 130**	**130 to 190**	**190 to 230**	**45 to 80**	**80 to 130**	**130 to 190**	**190 to 230**
Expected feed intake, lb/day[d]	**3.1**	**4.3**	**5.5**	**6.5**	**3.3**	**4.5**	**5.5**	**6.5**
	% of Diet							
Lysine, total	1.25	1.10	.90	.70	1.10	.95	.80	.65
Lysine, **digestible**	1.03	.90	.72	.56	.91	.77	.64	.51
Tryptophan	.23	.20	.16	.13	.20	.17	.14	.12
Threonine	.83	.72	.61	.48	.73	.63	.54	.44
Methionine	.33	.29	.23	.18	.29	.25	.21	.17
Methionine+cystine	.71	.62	.52	.41	.63	.54	.46	.38
Calcium	.90	.85	.80	.75	.85	.80	.75	.70
Phosphorus, total	.80	.75	.70	.65	.75	.70	.65	.60
Phosphorus, **available**	.51	.47	.44	.40	.47	.43	.39	.35
	Calculated Daily Intake, g							
Lysine, total	17.6	21.4	22.4	20.8	16.5	19.4	20.0	19.1
Lysine, **digestible**	14.4	17.5	18.1	16.4	13.6	15.8	16.0	15.0
Tryptophan	3.2	3.9	4.0	3.7	3.0	3.5	3.6	3.4
Threonine	11.6	14.1	15.2	14.1	10.9	12.8	13.6	13.0
Methionine	4.6	5.6	5.8	5.4	4.3	5.0	5.2	5.0
Methionine+cystine	10.0	12.2	13.0	12.1	9.4	11.1	11.6	11.1
Calcium	12.7	16.6	20.0	22.1	12.7	16.3	18.7	20.7
Phosphorus, total	11.3	14.6	17.5	19.2	11.2	14.3	16.2	17.7
Phosphorus, **available**	7.2	9.2	11.0	11.8	7.0	8.8	9.7	10.3

[a]All diets are full-fed under thermoneutral conditions.
[b]Digestible and available nutrient levels are calculations based on a corn-soybean meal diet.
[c]Sufficient data are not available to indicate that requirements for other nutrients are different from those in Table 11 for animals of these weights.
[d]Average dietary ME density is 1.5 Mcal/lb.

Table 16. Example dietary additions of salt, trace minerals and vitamins from concentrates, base mixes, or premixes[a, b]

Type of diet	Starter	Grower	Finisher	Breeding
Body wt, lb	8 to 45	45 to 130	130 to 250	
	------ Additions ------			
Minerals				
Salt, %	.3[c]	.3	.3	.5
Copper, ppm	10	8	6	10
Iodine, ppm	.25	.2	.15	.25
Iron, ppm	125	100	75	125
Manganese, ppm	15	12	9	30
Selenium, ppm[d]	.3	.3	.3	.3
Zinc, ppm	125	100	75	125
Vitamins				
Vitamin A, IU / lb	2500	2000	1500	3000
Vitamin D_3, IU / lb	250	200	150	300
Vitamin E, IU / lb	14	11	8.5	30
Vitamin K, mg / lb[e]	2	1.6	1.2	2
Riboflavin, mg / lb	5	4	3	5
Niacin, mg / lb	15	12	9	15
Pantothenic acid, mg / lb	10	8	6	10
Choline, mg / lb	0[f]	0	0	250
Biotin, mg / lb	0	0	0	.1
Vitamin B_{12}, mg / lb	.015	.012	.009	.01
Folic acid, mg / lb	0	0	0	.75

[a]If selenium is **not** included in the trace mineral premix, one trace mineral premix will supply these additions. The amount of trace mineral premix added / ton of feed will vary.
[b]Two vitamin premixes (one for starter to finisher and one for breeding swine) will supply these additions. The amount of vitamin premix added / ton of feed will vary.
[c]Adjust salt additions in the starter diet according to the quantity of dried whey and plasma proteins included in the diet. Dietary sodium levels > 3000 ppm are not likely to improve pig performance.
[d]Maximum legal addition is .3 ppm.
[e]Menadione activity.
[f]Soybean meal is an excellent source of choline. Starting diets containing less than 100 lb soybean meal / ton should contain 50 mg / lb of added choline.

Table 17. Amino acid ratios for pigs in relation to lysine (lysine =100)

Type of diet	Starter	Grower	Finisher	Gestation	Lactation
Body wt, lb	8 to 45	45 to 130	130 to 250		
Lysine	100	100	100	100	100
Tryptophan	18	18	18	19	18
Threonine	64	66	68	81	64
Methionine	26	26	26	26	25
Methionine + Cystine	57	57	58	67	48

Breeding Herd Management

A “limit-feeding” program is recommended for developing gilts after they reach about 230 lb and for gestating females and breeding boars. However, a “limit-feeding” program should limit only energy and not the intake of other nutrients, such as amino acids, minerals and vitamins. Energy intake is limited to keep animals from becoming too fat. Excessive feeding of breeding animals leads to increased feed cost and interferes with reproduction and longevity. Sows that are overfed immediately after breeding and throughout gestation often suffer high embryonic mortality, and thus produce smaller litters than sows fed proper amounts. Sows that have become too fat tend to have more farrowing difficulties, crush more pigs and eat poorly during lactation. This is especially true during the summer when sows are subject to heat stress.

The dietary nutrient recommendations for developing gilts, gestating females and breeding boars shown in Table 14 assume that they are fed 6, 4 and 5.5 lb of feed daily, respectively. When daily feed intake is adjusted, it is important that the concentrations of amino acids, minerals, and vitamins in the diet be adjusted accordingly. Aim to provide a constant daily intake of amino acids, minerals, and vitamins regardless of feed intake.

How much feed should gestating sows and developing gilts receive?

During mild weather (spring / fall) about 6 to 6.5 Mcal of ME per animal per day (4 to 4.5 lb of a corn or milo-soybean diet) will keep 350-- to 400-lb gestating sows in “good” condition. However, energy intake will need to be decreased or increased depending on the condition and weight of the sow and environmental conditions. See Table 18 for approximate energy and feed needs of gestating sows according to their body weight. Sows (350 to 400 lb) housed outside during the winter should receive about 7.5 to 9.0 Mcal of ME / day (5 to 6 lb of a corn or milo-soybean meal diet). Developing gilts should be restricted to about 90% of ad libitum feed intake or about 6 lb / day from about 230 lb until 2 weeks before mating.

Table 18. Approximate daily energy and feed needs of gestating sows and 1- to 2-year-old breeding boars[a]

	Sows		Boars	
Body wt, lb	**Mcal ME/day**	**lb feed/day[b]**	**Mcal ME/day**	**lb feed/day[b]**
300	5.4	3.7	5.9	4.0
400	6.5	4.4	6.9	4.7
500	7.4	5.0	7.9	5.3

[a]Animals housed on dry floors in crates in an environmentally controlled facility with minimal drafts and ambient temperature 65°F.
[b]Corn-soybean meal diet containing 1.5 Mcal ME / lb

How can limit-feeding of sows be accomplished?

The success of limit-feeding sows and gilts depends on controlling the intake of each animal. Care must be taken to see that each receives her share. Individual sow feeding stalls are effective devices for controlling boss sows. Interval feeding is another practical method for limiting the feed intake of sows during pregnancy. With interval feeding sows are allowed to consume two or three days worth of feed in one day and then wait two or three days before being provided access to feed again. Adjustments in daily intake are made by altering either the time on the feeder (2 to 12 hours) or time off the feeder (2 or 3 days). For example, two hours out of 72 is an adequate feeding time if enough feeder space is provided so all sows can eat at one time. With time on the feeders restricted, one feeder hole per sow is essential. More total feed is required during gestation when sows are interval-fed, because feed efficiency is reduced. For gilts every-third-day feeding is not recommended, because they gain less weight and farrow smaller pigs than gilts fed once daily. Gilts are not as able as sows to consume large quantities of feed in short time intervals.

What about flushing?

Litter size in limit-fed gilts can be increased by increasing their feed intake or allowing ad libitum access to feed beginning 11 to 14 days before mating. This is called “flushing.” Higher energy intake during this time will maximize the number of eggs released by the ovaries. Reduce feed intake to about 4 to 4.5 lb / day when mating occurs. Overfeeding during early gestation may increase embryonic mortality and reduce litter size.

Should feed intake be increased during late gestation?

The majority of fetal development occurs during the last 2 to 3 weeks of gestation. Research indicates that giving sows 2 to 3 lb more feed per day during the last 2 to 3 weeks of gestation can slightly improve the number of pigs weaned per litter. Do not give extra feed to fat sows during late gestation, or they probably will have poor feed intakes during lactation.

How should lactating sows be fed?

Sows should be full-fed during lactation to obtain maximum milk production, minimize weight loss and improve rebreeding performance. Many sows perform best when they are allowed to consume all the feed they can beginning the day they farrow. Severe feed restriction after farrowing predisposes sows to constipation and delayed return to estrus. It is easier for some people, however, to detect lactational problems in sows if they are offered limited amounts of feed during the first 3 days after farrowing. If limit-feeding is practiced, provide at least 3 lb of feed the day of farrowing and increase the offering 3 lb / day thereafter. By day four postfarrowing, the sow should be given ad libitum (free choice) access to feed. Record the amount of feed added to the sow’s feeder daily, especially if more than one person is feeding the sows.

How about feeding after weaning?

After weaning, feeding rate will depend on how adequately the female was fed during lactation and her body condition. Generally, 4 to 4.5 lb / day of a corn or milo-soybean meal diet is adequate. Provide 5 or more pounds of feed / day to thin sows. Do not withhold feed from sows after weaning, because it reduces subsequent litter size.

How should developing and breeding boars be fed?

Guidelines for feeding developing boars are shown in Table 15. When the boars weigh about 230 lb they should begin to receive restricted quantities of feed to avoid excessive weight gain. Offer the boars about 5 to 5.5 lb of a corn or milo-soybean meal diet / day (about 7.5 Mcal of ME / day). The diet should contain nutrient levels similar to those for developing gilts shown in Table 14. When boars are between about 1 year and 2 years of age, we suggest they be fed to gain about .4 to .55 lb / day (145 to 200 lb / year). To accomplish this and maintain fertility, feed breeding boars a different diet than the one used for gestating females. The goal is to restrict energy intake to slow growth rate, but to maintain high amino acid, vitamin and mineral intakes to preserve fertility and libido. Weigh boars periodically to determine the appropriate feeding rate for specific conditions. Table 18 gives approximate energy and feeding rates to allow boars to gain about .4 to .55 lb / day. Boars > 2 years of age should be fed to gain at a slower rate, because they are nearing their mature body size. As with sows, the daily feeding rate must be changed to reflect differences due to housing temperature and body condition of the boar.

What role does fiber or nonstarch polysaccharides have in sow diets?

Plant-based feed ingredients contain fiber or nonstarch polysaccharides (NSP) which cannot be digested by pigs. Instead NSP are fermented by microorganisms in the large intestine. The most abundant NSP in plants include cellulose, hemicelluloses and pectins. Gestating sows are excellent candidates to receive high NSP-containing diets. Limit-fed gestating sows obtain more energy from fibrous feedstuffs than growing pigs do and they have a higher fermentation capacity in the hindgut. In addition, sows can consume more of a concentrate diet than necessary to meet their energy requirement during gestation. This excess feed intake capacity can be exploited by including low-energy, bulky feeds in the diets of gestating sows.

Litter size weaned may be improved by about .5 pigs / litter when NSP is added to the sow diet during gestation. In addition, NSP in the sow diet may improve sow longevity in the herd. To maximize the chance of an improvement in sow reproductive performance from increased NSP intake, it seems sows should consume 350 to 400 g / d of neutral detergent fiber (NDF) during gestation. Diets containing 45% wheat midds, 20% soybean hulls, 25% alfalfa meal, 30% sugar beet pulp, or 40% oats provide sows about 350 g / d of NDF. There is no strong evidence that increasing the NSP level in the lactation diet improves sow reproductive performance. Fibrous ingredients in the lactation diet may help control constipation, however (see the next question). Bulky diets containing a high level of NSP results in a sow that is more “satisfied” after consuming a meal than one fed typical corn or milo-soybean meal-based diets. The same situation has been observed with breeding boars. Consider that the costs associated with manure handling may increase due to the larger volume of solids produced when high NSP diets are fed.

Can sow constipation be controlled by feeding a specific feed ingredient?

Maybe. Results with laxatives are variable. Most of the published research indicates that laxatives do not improve sow reproductive performance. Often sows are constipated because they are not given enough feed during the first few days after farrowing. If sows are constipated, try offering them more feed after farrowing before adding a laxative to the diet. Also, check that the sows have an ample supply of water.

Fibrous feedstuffs or certain chemicals may serve as laxatives. Fibrous feedstuffs such as beet pulp, alfalfa, oats, pysillium, soybean hulls and wheat bran have a high water binding capacity and can act as a laxative. Chemical laxatives include potassium chloride (15 lb / ton), Epsom salts (30 lb / ton), and Glauber salts (60 lb / ton). These inclusion rates are recommended when sows are fed 4 to 4.5 lb of feed / day. The level can be cut in half when sows are full-fed. Natural laxative feedstuffs are preferred because mineral salts may alter water balance in the body and irritate the digestive system. Limit the amount of beet pulp, alfalfa, oats and wheat bran in the diet according to guidelines in Table 1 to avoid reducing the energy density of the diet too much.

How does fat affect breeding herd performance?

Feeding fat to sows during late gestation may improve pig preweaning survival rate by 2 to 3%. The greatest response to dietary fat is achieved in herds in which pig preweaning survival rate is less than 80%. For best results, sows should consume at least 2.5 lb of added fat before farrowing to improve pig survival rate. Feeding a lactation diet with 3% added fat at the rate of 6 lb / day for 14 days before farrowing would be sufficient.

Sow feed intake usually decreases when fat is added to the lactation diet; however, energy intake may be increased slightly, especially during hot weather. A greater increase in energy intake is likely during hot weather when sows are drip-cooled. Much of this additional energy consumed by sows fed fat-supplemented diets is made available to the litter via the milk. Consequently, added fat may increase litter gain but does little to reduce sow weight loss during lactation.

How can developing or replacement gilts be fed to reduce the number of “downer sows”?

The dietary calcium and phosphorus levels we recommend for growing-finishing pigs shown in Table 11 support excellent rates of gain and feed efficiency, but are not sufficient to build the skeletal structure and mineral reserves needed by developing gilts to reduce “downer sow” problems. The dietary phosphorus level necessary to achieve maximum growth and feed efficiency is at least .1% less than that needed to achieve maximum bone mineralization. Thus, we recommend that developing gilts from 45 to 230 lb be fed diets containing the levels of calcium and phosphorus shown in Table 15.

Dietary calcium and phosphorus recommendations for gilts after they are placed on a limit-feeding program at about 230 lb are shown in Table 14.

Will higher dietary levels of calcium, phosphorus, and other nutrients improve feet and leg soundness?

Probably not, although proper nutrition is clearly important in maintaining feet and leg soundness. Many research studies have investigated the influence of nutrition on feet and leg soundness. As long as the diets contained nutrient densities similar to the recommendations in this publication, no relationship between nutrition and feet and leg soundness was found. In other words, if pigs are fed according to the guidelines in this publication, any feet and leg soundness problems encountered likely are caused by genetic or environmental factors other than nutrition.

Growing Pig Management

Pigs undergo many physiological changes between weaning and market weight. The digestive system converts from one best suited to using milk to one suitable for the breakdown and absorption of complex carbohydrates and proteins found in grain and soybean meal. Daily feed intake normally increases steadily between weaning and market weight. Lean growth rate reaches a plateau when the pigs weigh about 130 lb and declines thereafter. These changes are the basis for the feeding recommendations listed for growing-finishing pigs in this nutrition guide.

Pigs should have ad libitum access to feeds reformulated to contain different ingredients and nutrient densities as they grow. This is commonly called “phase feeding.” Phase feeding is essential to optimizing pig performance and controlling feed costs in a swine enterprise by limiting the time that nutrients are over- or underfed. In addition, phase feeding reduces the amount of nitrogen and phosphorus pigs excrete. Starting pigs weighing less than about 25 lb should be fed diets containing several specialty ingredients. Thereafter, switch them to grain-soybean meal-based diets containing few, if any, specialty ingredients. Reduce the nutrient density of the diet as pigs approach market weight.

How does fat affect growing pig performance?

In growing-finishing pigs, fat consistently improves feed efficiency. On average, feed efficiency is improved by 2% for each 1% increment of added fat. Feed efficiency and daily gain are improved more by feeding fat to pigs during the summer than the winter. For example, daily gain may be increased by 1% for each 1% addition of fat in the summer, whereas little, if any, improvement in gain is expected in the winter. Carcass fat content is not greatly altered unless added fat levels exceed 5% of the diet and the amino acid:calorie ratio in the diet is not maintained constant. Energy intake is a major factor limiting lean growth rate in pigs weighing less than about 130 lb. Fat additions to grain-soybean meal diets may increase energy intake, especially in hot weather, and improve lean growth rate in young pigs. On the other hand, added fat is less valuable in finishing pigs, because energy intake from grain-soybean meal diets is often sufficient to maximize lean growth rate. Fat often is added to starting pig diets to aid in the manufacture of pelleted, milk product-based diets. Also, research indicates that as little as 2.5% added fat (50 lb / ton) reduces dust in confinement buildings by about 25%. Similar effects are observed in feed mills. Reduced dust levels have improved health implications for both pigs and people.

What happens when diets contain too much protein?

Feeding excessive amounts of protein and amino acids usually wastes money, results in increased nitrogen excretion, and reduces growth rate and feed efficiency. A greater amount of nitrogen in the manure has the potential for contaminating the environment, including increasing the level of ammonia in the atmosphere. Pigs also will consume more water and they may exhibit a mild diarrhea.

Should high levels of zinc be added to starting pig diets?

Nutritionists typically add 100 to 150 ppm of zinc to starting pig diets to meet requirements for growth. Recently there has been interest in feeding nursery pigs diets containing 2,000 to 3,000 ppm of zinc to combat postweaning stress and diarrhea. Also, zinc ions cause the organism responsible for swine dysentery (*S. hyodysenteriae*) to produce less toxin. Research results indicate the response to high levels of zinc in the diet is highly variable; in some studies no change in growth rate or feed efficiency has been observed, but in others the response has been large (Table 7). Also, feces are made firmer by high levels of zinc in the feed. However, questions remain about how zinc-containing manure may affect anaerobic lagoons and the soil. Over 99% of the zinc fed to pigs is excreted in the manure. These factors suggest that the decision to use high levels of zinc should be made on a case-by-case basis. Careful monitoring of pig performance when high levels of zinc are added is recommended. It is important that the extra zinc be supplied by zinc oxide; otherwise toxicity problems may develop. Add 2,500 to 3,000 ppm (7.0 to 8.3 lb of zinc oxide / ton of complete feed assuming the zinc oxide contains 72% zinc) to feed for a maximum of 28 days postweaning, because zinc at these levels may be toxic. Maintain about 10 ppm of copper in any diet containing 2,000 to 3,000 ppm of zinc, because there is no additional growth response from higher dietary copper fortification.

What about separate sex feeding?

Penning barrows separately from gilts and feeding them different diets allows producers to gain better precision in feeding pigs. The feed intake of gilts and barrows begins to differ significantly when they weigh about 80 lb. From 80 lb until market weight, gilts consume about 8% less feed than barrows do, but they deposit lean tissue at least as fast as barrows. Thus, gilts need diets with a greater concentration of amino acids than barrows do; otherwise they will experience slower growth and poorer efficiency of gain, and produce carcasses with lower lean content than their potential. The decision to separate barrows from gilts and feed them different diets should be based on the producer's production and marketing goals. A marketing system that rewards carcass leanness (value-based) usually is necessary to maximize returns from separate sex feeding. We have provided separate amino acid recommendations for barrows and gilts in this publication.

What nutritional technologies are available to reduce carcass backfat or improve leanness?

The most effective way to reduce backfat or improve leanness is through genetic improvement. Nutritional strategies that maximize lean growth and minimize excess energy intake over that required for maximum lean growth will produce the leanest carcasses. See Table 7 for a list of feed additives that are effective in reducing carcass backfat or improving leanness. Other technologies are described below.

- *Limit-feeding*

The principle behind limit-feeding is to reduce the amount of excess energy pigs have available for fat synthesis. Research shows that restricting feed intake of finishing pigs (> 125 lb) to 80 or 85% of ad libitum causes an 11 to 17% (about .15 inches) reduction in 10th-rib backfat. However, the number of days to market increases by about two weeks. Limit-feeding can be done by restricting the time pigs have access to self feeders or floor feeding several times each day. We do not recommend limit-feeding to 80 or 85% of ad libitum intake, because currently the increased production costs (which include increased management to monitor and adjust feed delivery devices) generally are not offset by a higher carcass premium.

- *Dietary amino acid level*

In general, as dietary amino acid density increases, carcass backfat decreases. However, a large increase in the lysine level of finisher diets causes a relatively small reduction in backfat. In a recent large study, a 47% increase in dietary lysine level (from .59 to .87%) for medium lean gain finishing barrows reduced their backfat by 6% or .08 inches. No additional reduction in backfat was observed when the diet contained more than .73% lysine. In gilts, carcass backfat was reduced by 11% or .11 inches when dietary lysine level was increased from .59 to .87% during the finishing phase.

- *Betaine*

A byproduct of sugar beet processing, betaine currently is being evaluated in finishing pig diets. In some cases backfat has been reduced by 8 to 14% when diets containing 1,250 ppm of betaine were fed for 35 to 40 days before slaughter. On the other hand, some studies have shown no response to betaine supplementation. We believe the response to betaine in corn or milo-soybean meal diets is not consistent enough to warrant routine use. Thus, evaluate the use of betaine on a case-by-case basis.

Example Diets

Example diets for all classes of swine are presented in Tables 19, 21, 22, 24 and 25. Ingredient analysis values in Table 29 were used to formulate the diets. Diets containing added fat were formulated to contain the same lysine:calorie ratio as diets without added fat. Fat reduces feed intake and unless the amino acid density is increased pig performance may be compromised due to a shortage of amino acids relative to calories. In general, these diets promote best-cost gain. Because ingredient price and availability are not constant, consider using alternate feedstuffs to optimize cost of gain. Refer to Tables 1 and 2 for guidelines when using alternate energy and protein sources.

Diets for 8 to 45 lb pigs

For reasons explained in the *Methods of Supplying Nutrients* section we recommend that most producers purchase complete pelleted diets for starting pigs weighing less than about 25 lb. We present example starting diets to show many of the typical ingredients used in starting diets today. It is necessary to use at least three different diets for starting pigs up to 45 lb to achieve good performance at low cost.

The starter 1/transition diet (Table 19) is a multipurpose diet. That is, it can be introduced to pigs before weaning as creep feed, fed to starting pigs from 8 to 13 lb body weight, or provided to pigs heavier than 13 lb at weaning. Creep feeding is recommended beginning at about 10 days of age for pigs weaned at 3 to 4 weeks of age and later. There is general agreement that a positive correlation exists between weight at weaning and

Table 19. Example diets for 8 to 45 lb growing pigs

Ingredient	Starter 1/ transition[a] (8 to 13 lb)	Starter 2 (13 to 25 lb)[b]		Starter 3 (25 to 45 lb)[b]	
	1	1	2	1	2
Corn	605	891	882	1209	1044
Soybean meal, 44% CP	189	620	615	712	720
Soy protein concentrate	60				
Dried whey, edible	550	300	300		100
Plasma proteins, spray-dried	120				
Oat groats	250				
Fish meal, select menhaden	100		80		
Blood meal, spray-dried		50			
Fat (stabilized)	60	60	60		60
L-Lysine • HCl	3	1	1	1	1
DL-methionine	2	2	1		
Dicalcium phosphate (22% Ca, 18.5% P)	11	25	13	24	22
Limestone	13	18	15	19	18
Salt	2	4	4	6	6
Vitamin mix[c]	5	5	5	5	5
Trace mineral mix[c]	3	3	3	3	3
Copper sulfate		1	1	1	1
Zinc oxide (72% Zn)	7				
Antibiotic	20	20	20	20	20
Total	2000	2000	2000	2000	2000
Calculated analysis:					
Lysine, %	1.55	1.35	1.35	1.20	1.24
Lysine:calorie, g / Mcal ME	4.6	4.0	4.0	3.7	3.7
Protein, %	21.6	21.4	21.6	20.7	20.8
Calcium, %	.90	.85	.85	.75	.75
Phosphorus, %	.77	.67	.67	.62	.62

[a]Provide a total of 4 lb / pig (at least 3 lb after weaning) to pigs > 13 lb at weaning, but < 28 days of age.
[b]Ground whole oats can replace up to 300 lb of corn / ton if edema disease is a problem. Milo can substitute for corn.
[c]See Table 16 for nutrient levels. Amount added / ton of feed will depend on the carrier.

Table 20. Suggested distribution of starting feed according to pig weaning age[a]

Diet (body wt, lb)	Weaning age, days 14	21	28
	----lb / pig----		
Starter 1 / transition (8 to 13)	6	3	3
Starter 2 (13 to 25)	15	15	12
Starter 3 (25 to 45)	45	45	45
Total	66	63	60

[a]See Table 19 for ingredient composition.

subsequent performance. Pigs that are heavier at weaning usually maintain their weight advantage to market weight. Therefore, creep feeding should be considered if it will result in a heavier pig at weaning. For pigs weaned at less than 3 weeks of age, the value of creep feed is questionable, because they often consume very little feed. The quality of the creep diet and how it is managed has a significant impact on whether creep feeding succeeds. Encourage creep feed consumption by providing small amounts of feed in a shallow pan or on the floor several times each day. Be sure the pigs have access to fresh water.

Producers who wean pigs at about 2 weeks old (8 lb body weight) should feed the starter 1 diet until the pigs weigh about 13 lb. In addition, any pig that weighs more than 13 lb at weaning, but is less than 28 days of age, should be provided about 3 lb of the starter 1 diet before it is given the starter 2 diet. Body weight is not a good indicator of a weaned pig's ability to digest diets containing large amounts of the complex carbohydrates and proteins found in grain and soybean meal. Providing limited amounts of a highly digestible, nutrient dense diet after weaning helps pigs make the transition to dry feed.

Table 20 shows suggested total intakes of each starter diet according to pig weaning age. Many producers control nursery feed costs by planning to feed a predetermined quantity of each diet. When the designated amount of a first diet is consumed, pigs are switched to the next, less expensive, diet in the sequence. It is important to monitor the weight of a few pigs chosen at random about every two weeks to determine if the pigs are growing as expected. Checking growth rate helps ensure pigs are switched to the next diet in the sequence at the proper time.

Diets for 45 to 250 lb pigs

Diets for growing-finishing pigs are shown in Tables 21 and 22. Table 23 presents examples of how feed during the growing-finishing phase may be distributed depending on the pigs' growth rate. Many producers switch diets according to estimated pig weight. An alternative method would be to provide a predetermined amount of each diet. When that amount is consumed, switch pigs to the next diet in the sequence. This eliminates guessing

Table 21. Example diets for 45 to 130 lb growing pigs[a]

	Grower 1 (45 to 80 lb)			Grower 2 (80 to 130 lb)	
Ingredient	**1**	**2**	**3**	**4**	**5**
Corn or milo	1367	1419	1272	1489	1319
Soybean meal, 44% CP	580	525	615	464	
L-Lysine • HCl		2			
Fat (stablized)			60		
Soybeans, full-fat, cooked					635
Dicalcium phosphate (22% Ca, 18.5% P)	22	23	22	17	15
Limestone	18	18	18	17	18
Salt	6	6	6	6	6
Vitamin mix[b]	4	4	4	4	4
Trace mineral mix[b]	3	3	3	3	3
Total	2000	2000	2000	2000	2000
Calculated analysis:					
Lysine, %	1.00	1.00	1.04	.85	.88
Lysine:calorie, g:Mcal ME	3.1	3.1	3.1	2.6	2.6
Protein, %	18.4	17.5	18.8	16.4	16.7
Calcium, %	.70	.70	.70	.60	.60
Phosphorus, %	.58	.58	.58	.51	.51

[a]Assumes a mixture of medium lean gain barrows and gilts. All diets are full-fed under thermoneutral conditions.
[b]See Table 16 for nutrient levels. Amount added / ton of feed will depend on the carrier.

Table 22. Example diets for 130 to 250 lb finishing pigs[a]

	Finisher 1 (130 to 190 lb)			Finisher 2 (190 to 250 lb)		
Ingredient	**1**	**2**	**3**	**1**	**2**	**3**
Corn or milo	1613	1665	1548	1731		1646
Barley					1888	
Soybean meal, 44% CP	345	290	370	230	75	
L-Lysine • HCl		2				
Fat (stabilized)			40			
Soybeans, full-fat, cooked						315
Dicalcium phosphate (22% Ca, 18.5% P)	14	16	14	12	8	11
Limestone	17	16	17	16	18	17
Salt	6	6	6	6	6	6
Vitamin mix[b]	3	3	3	3	3	3
Trace mineral mix[b]	2	2	2	2	2	2
Total	2000	2000	2000	2000	2000	2000
Calculated analysis:						
Lysine, %	.70	.70	.72	.55	.49	.56
Lysine:calorie, g:Mcal ME	2.1	2.1	2.1	1.7	1.7	1.7
Protein, %	14.3	13.4	14.6	12.2	12.3	12.4
Calcium, %	.55	.55	.55	.50	.50	.50
Phosphorus, %	.47	.47	.47	.43	.43	.43

[a]Assumes a mixture of medium lean gain barrows and gilts. All diets are full-fed under thermoneutral conditions.
[b]See Table 16 for nutrient levels. Amount added / ton of feed will depend on the carrier.

Table 23. Examples of growing-finishing feed usage according to pig growth rate[a]

	Average daily gain (lb/day) from 45 to 250 lb		
Diet (body wt, lb)	**1.6**	**1.8**	**2.0**
	------------------------lb of feed / pig--------------------		
Grower 1 (45 to 80)	90	80	75
Grower 2 (80 to 130)	160	140	125
Finisher 1 (130 to 190)	205	180	165
Finisher 2 (190 to 250)	240	210	190
Total	695	610	555

[a]Corn or milo-soybean meal diets fed to barrows and gilts under thermoneutral conditions with minimal feed wastage.

the weight of pigs to decide when to switch diets and the possibility of feeding higher nutrient dense diets too long. It is important to monitor the weight of a few pigs chosen at random every three to four weeks to determine if the pigs are growing as expected. Checking growth rate helps ensure pigs are switched to the next diet in the sequence at the proper time. Phase feeding is most convenient when facilities are operated on an all-in / all-out basis. Producers who have not fed pigs in this manner and who do not know the feed intake patterns of their pigs can use the information in Table 23 as a reference. Average daily gain data for growing-finishing pigs is needed to use Table 23.

Diets for the breeding herd

Suggested gilt developing, gestation, breeding boar, and lactation diets are shown in Tables 24 and 25. The gestation diets shown are designed to be fed so that sows receive 5.9 Mcal of ME / day. If a different amount of energy intake is required, reformulate the diets as described earlier. Feed used for the breeding herd will be about 2,200 lb / animal / year in well managed, confinement gestation units. That increases to about 2,500 lb / animal / year in outdoor accommodations.

Tools for Quantifying Performance

We have provided nutrient recommendations based on fat-free lean growth rate, 21-day litter weight and feed intake in this publication. These factors influence the quantity of nutrients pigs require. By monitoring pig performance, it is possible to formulate diets to specific production situations and

Table 24. Example diets for gestating sows, breeding boars, and developing gilts (230 lb to breeding)

	Gestation					Breeding boar and developing gilt
Ingredient	**1**	**2**	**3**	**4**	**5**	**1**
Corn or milo	1678	1588	1233	1400		1577
Barley					1836	
Oats			500			
Alfalfa hay, 16% CP				400		
Soybean meal, 44% CP	235		184	131	90	350
Soybeans, full-fat[a]		324				
Dicalcium phosphate (22% Ca, 18.5% P)	47	48	44	43	32	34
Limestone	17	17	16	3	19	16
Salt	10	10	10	10	10	10
Vitamin mix[b]	10	10	10	10	10	10
Trace mineral mix[b]	3	3	3	3	3	3
Total	2000	2000	2000	2000	2000	2000
Daily intake:						
Feed, lb	4.0	3.9	4.2	4.4	4.6	6.0[c]
ME, Mcal	5.9	5.9	5.9	5.9	5.9	8.9
Lysine, g	10.0	10.1	10.0	10.0	10.4	19.0
Protein, g	220	218	229	237	259	387
Calcium, g	16.3	16.3	16.2	16.4	16.3	20.4
Phosphorus, g	13.6	13.5	13.5	13.6	13.6	17.7
Calculated analysis:						
Lysine, %	.55	.57	.52	.50	.50	.70
Lysine:calorie, g:Mcal ME	1.7	1.7	1.7	1.7	1.7	2.2
Protein, %	12.1	12.3	12.0	11.9	12.4	14.2
Calcium, %	.90	.92	.85	.82	.78	.75
Phosphorus, %	.75	.76	.71	.68	.65	.65

[a]Raw or cooked.
[b]See Table 16 for nutrient levels. Amount added / ton will depend on the carrier.
[c]Provide breeding boars 5.5 lb / day to meet daily nutrient recommendations in Table 14.

Table 25. Example diets for lactating sows

	Lactation			
Ingredient	**1**	**2**	**3**	**4**
Corn	1407	1322	1233	1294
Soybean meal, 44% CP	510	535		625
Fat (stabilized)		60		
Soybeans, full-fat[a]			685	
Dicalcium phosphate (22% Ca, 18.5% P)	43	42	41	39
Limestone	17	18	18	19
Salt	10	10	10	10
Vitamin mix[b]	10	10	10	10
Trace mineral mix[b]	3	3	3	3
Total	2000	2000	2000	2000
Calculated analysis:				
Lysine, %	.90	.93	.92	1.05
Lysine:calorie, g:Mcal ME	2.8	2.8	2.8	3.3
Protein, %	17.1	17.3	17.2	19.1
Calcium, %	.90	.90	.90	.90
Phosphorus, %	.75	.75	.75	.75

[a]Cooked. Raw soybeans have resulted in decreased pig weaning weights and increased sow weight loss during lactation compared with soybean meal.
[b]See Table 16 for nutrient levels. Amount added / ton of feed will depend on the carrier.

reduce the consequences of underfeeding or overfeeding nutrients. This section will describe tools to use in quantifying pig performance. The procedures involve feeding high nutrient dense diets to a sample of pigs to evaluate their performance when dietary nutrient density is not likely a limiting factor. Once the performance potential of the pigs is known, diets can be formulated.

How do I estimate fat-free lean growth rate?

There are several methods to measure lean growth in swine. First, you can determine the quantity of lean in the pig initially and in the carcass at slaughter and the number of days on test. Use the following formula to estimate rate of fat-free lean gain:

$$\text{lb lean / day on test} = \frac{\text{final lb lean - initial lb lean}}{\text{days on test}}$$

Final pounds of lean in the carcass can be obtained by using the lot average for fat-free lean index (FFLI) and hot carcass weight. This information is provided on packer kill sheets in the Nebraska and South Dakota area. The FFLI is the percentage of edible, lean meat in a carcass, factoring out intramuscular fat (i.e., marbling). Because the FFLI adjusts lean content to represent no intramuscular fat, it will normally be 5 to 7% less than customary percent lean values. Daily lean gain using the FFLI results in lean gain with 0% fat, therefore the values will be lower than lean gain expressed on a 5% fat basis. Use the following formula to estimate pounds of lean in the carcass:

$$\text{lb of lean} = (\text{FFLI} / 100) \times \text{HCWT}$$

where FFLI = fat-free lean index

HCWT = hot carcass weight, lb

To estimate pounds of fat-free lean in a 40 to 50 lb pig use the following equation:

lb of fat-free lean initially = .95 x [-3.65 + (.418 x live wt, lb)]

For example, assume that a group of pigs averaging 45 lb initially was tested for 100 days. At slaughter, the group average for hot carcass weight and FFLI was 180 lb and 45, respectively. What is the average fat-free lean growth rate for the group?

.95 x [-3.65 + (.418 x 45)] = 14.4 lb of lean initially

(45 / 100) x HCWT = 81 lb of lean at slaughter

$\frac{81 - 14.4 \text{ lb}}{100 \text{ days}}$ = .67 lb of fat-free lean per day on test

A second and quicker method of estimating fat-free lean gain is shown in Table 26. Find the pigs' FFLI across the top of the table and average daily gain on the left side. For example, a group of pigs having a FFLI of 45 and an average daily gain of 2.0 lb / day will have an estimated fat-free lean gain of .66 lb / day from 45 to 250 lb.

The most accurate method to measure the lean growth of your herd is to determine the lean growth curve of your growing-finishing pigs. This involves a minimum of five ultrasonic scannings at specific intervals throughout the growth phase on a representative sample of pigs. Also, feed intake measurements must be obtained throughout the growth phase. The scan data and feed intake data are then sent to Purdue University where the specific lean growth curve for individual farms are generated. While this is the most costly method, it also provides one of the greatest opportunities to formulate diets for a given level of performance

The equations for calculating the FFLI are being revised as this publication goes to press. We used the FFLI provided by the National Pork Producers Council in 1994 as the basis for the feeding recommendations in this publication.

Table 26. Estimated daily fat-free lean gain (lb/day) using the fat-free lean index and average daily gain[a]

	Fat-free lean index, %							
Daily gain, lb	40	42	44	46	48	50	52	54
1.2	.35	.37	.39	.41	.44	.46	.48	.50
1.4	.41	.43	.46	.48	.51	.53	.56	.58
1.6	.47	.49	.52	.55	.58	.61	.64	.67
1.8	.52	.56	.59	.62	.65	.69	.72	.75
2.0	.58	.62	.65	.69	.73	.75	.80	.83
2.2	.64	.68	.72	.76	.80	.84	.88	.92
2.4	.70	.74	.78	.83	.87	.91	.96	1.00

[a]Starting and final weights are 45 and 250 lb, respectively. Carcass weight is 185 lb.

Table 27. Adjustment factors for 21-day litter weight according to weaning age[a]

Age weighed, days	Factor	Age weighed, days	Factor
14	1.30	21	1.00
15	1.25	22	.97
16	1.20	23	.94
17	1.15	24	.91
18	1.11	25	.88
19	1.07	26	.86
20	1.03	27	.84
		28	.82

[a]Adapted from National Swine Improvement Federation, 1997.

Farm-specific feeding programs for growing-finishing pigs are best established by conducting growth trials. Do this by randomly selecting 10 to 20 % (equal numbers of each sex if separate sex feeding is not practiced on the farm) of the pigs from a farrowing group for each test. Pigs should weigh between 40 and 50 lb at the beginning of the test. Weigh the pigs and manage them normally to market weight. To ensure that nutrient intake is not limiting lean growth, feed diets containing 10% higher amino acid levels than those shown for high lean gain pigs in Tables 12 and 13. Terminate the test when the pigs average about 250 lb. Repeat the test quarterly during the first year and semiannually thereafter. Record feed disappearance so nutrient intake can be estimated. Information should be available from at least three tests before a final decision is made regarding whether to classify the pigs as high, medium or low lean gain.

■ What is the best way to obtain 21-day litter weights?

Litters should be standardized to between 8 and 10 pigs per litter within 24 to 48 hours after birth. Collect litter weights before weaning and as near 21 days of age as possible. Litters may be weighed between 14 and 28 days and the weights adjusted to a 21-day basis (Table 27). For example, a litter weighed 120 lb at 19 days of age. The 21-day litter weight would be 128.4 lb (120 x 1.07). If creep feed is offered, it is important that litter weights be obtained by 21 days of age to minimize the influence of creep feed intake on 21-day litter weights. In genetic selection programs the 21-day litter weight is adjusted for parity and number of pigs after transfer. We do not believe these adjustments are necessary to apply the concepts outlined in this publication.

Provide groups of lactating sows diets containing 1.15% lysine and collect 21-day litter weights. Repeat the test quarterly during the first year and semiannually thereafter. Record feed disappearance so nutrient intake can be estimated. Information should be available from at least three tests before a final decision is made regarding whether to classify the sows as capable of producing litters weighing more or less than 120 lb at 21 days of lactation. Amino acid recommendations for lactating sows producing litters weighing less than or greater than 120 lb at 21 days are shown in Table 14.

How can I estimate feed intake?

Producers who operate buildings or rooms on an all-in / all-out basis can use closeout information. Those with continuous flow production are advised to closely monitor identified pens of pigs or groups of sows. To estimate lactating sow feed intake attach a card to each farrowing crate and record the amount of feed added to the sow's feeder daily. General guidelines for daily feed intake of pigs are shown in Tables 11, 12, 13, 14 and 15.

Methods of Supplying Nutrients

Making sound decisions about the method(s) used to supply pigs nutrients is an important part of feed program design. However, the terminology used to describe the methods of supplying pigs nutrients often is confused. There are four basic methods of supplying nutrients to pigs: 1) purchased **complete feed**; 2) grain plus **concentrate or supplement**; 3) grain plus soybean meal and **basemix**; or 4) grain, plus soybean meal, salt, calcium and phosphorus source(s) and **premix**. A description of each of these options follows.

Complete feed. A ready-to-feed product containing ingredients that when combined meet the total nutritional needs of the pig. The feed manufacturer assumes all responsibilities for ingredient quality and mixing errors. The producer is responsible for using the product correctly.

Concentrate or supplement. A mixture of ingredients formulated to complement nutrients present in grain. When it is correctly mixed with grain, the resulting diet will meet the total nutritional needs of pigs. Typical inclusion rates are 300 to 500 lb / ton for all classes of pigs except starting pigs. The producer's task is to mix the correct ratio of concentrate and grain.

Basemix. A product generally containing ingredients rich in minerals and vitamins. Basemixes correctly mixed with grain and a protein source(s) will satisfy the total nutritional needs of pigs. Some basemixes may contain crystalline lysine and animal protein products. Typical inclusion rates are 50 to 100 lb / ton, although some basemixes for nursery diets are added at 200 to 400 lb / ton. The producer assumes the responsibility for variation in the quality of the protein source(s) and for correct blending of ingredients.

Premix. A product containing sources of vitamins and(or) trace minerals. The total nutritional needs of pigs can be met by combining premixes with grain, salt and sources of protein, calcium and phosphorus. Typical inclusion rates are 5 to 10 lb / ton. Premixes are available with trace minerals and vitamins combined or packaged separately. The producer assumes more responsibility for correct diet formulation and preparation and variation in the quality of the protein, calcium and phosphorus sources with this option than with the three other options.

The example diets shown in Tables 19, 21, 22, 24 and 25 are based on a premix program. We do not necessarily endorse a premix program. Our intent is to show common ingredients used to supply the major classes of nutrients necessary in a diet for pigs.

How does one choose which method to use?

One method does not consistently promote better pig performance or a lower cost of gain than another. The major factors we think should be considered in choosing a method of supplying nutrients to pigs are shown in Table 28. Convenience refers to the level of involvement the producer has in making nutritional decisions and feed preparation. Risk is the odds of a diet not containing the intended concentration of nutrients and quality of ingredients. Risk rates the transfer of responsibility from the feed manufacturer to the producer as the producer assumes more or less responsibility for proper quality control and inclusion of nutrient sources in swine diets. Service is the amount of technical advice, farm recordkeeping and other perks offered. Cost includes costs of ingredients and services such as process ing, blending, delivery, technical advice, etc.

Table 28. Considerations in choosing a method of providing pigs nutrients

Method	Convenience	Risk (Quality)	Service	Cost[a]
Complete	high	low	high	high
Concentrate	↓	↑	↓	↓
Basemix				
Premix	low	high	low	low

[a]Includes costs of ingredients and services.

Producers who put a high priority on convenience, minimal risk of having feed quality problems, and ample service will want to use complete feeds. However, cost is generally higher to justify the manufacturer's assumption of these risks and services offered. On the other hand, there is less cost in a premix program, but it is a less convenient, higher risk, and lower service-oriented program. The risks associated with feed quality can be managed but it takes a commitment of time and resources. See the sections on *Feed Processing and Ingredient Quality* for details on preparing quality pig feed. ***Select the method which provides the best balance of factors you consider important while maintaining a competitive feed cost per unit of gain.***

What about mixing feed on the farm?

Choices for producers range from purchasing individual ingredients and manufacturing diets on the farm to purchase and delivery of complete feeds in meal or pellet form. Compare the fixed and operating costs associated with manufacturing feed on the farm to custom rates at local feed mills to decide which option to use. Generally, because of problems with stocking several ingredients and the difficulty in securing and maintaining quality, fresh ingredients such as dried whey and fishmeal, we recommend that most producers purchase complete pelleted feeds for starting pigs weighing less than about 20 to 25 lb. When feed for pigs weighing less than 20 to 25 lb is made on the farm, we recommend it be mixed using a basemix or concentrate that contains many of the specialty ingredients shown in the example diets in Table 19.

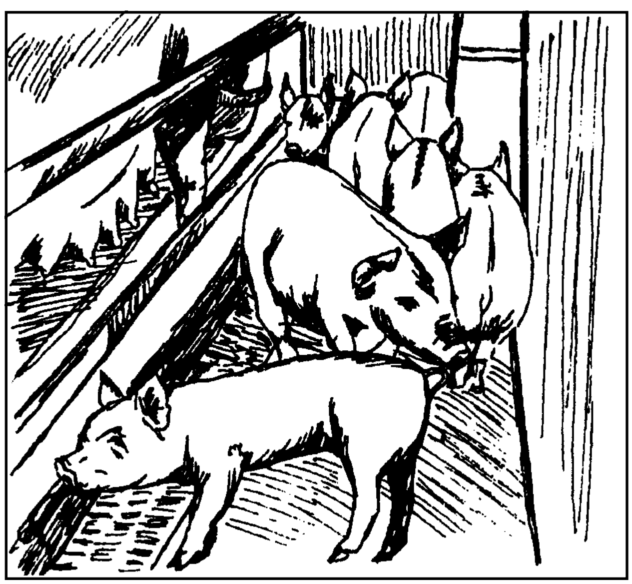

Table 29. Ingredient composition (as-fed basis)

Feedstuff	Protein %	Lysine %	Trypto-phan %	Threo-nine %	Methio-nine %	Methio-nine + cystine %	Cal-cium %	Phos-phorus %	Available Phos-phorus %	Meta-bolizable energy kcal/lb	Fat %	Crude Fiber %
Alfalfa meal, dehy	17.0	.74	.24	.70	.25	.43	1.53	.26	.26	750	2.6	24.0
Alfalfa hay, early bloom	16.0	.68	.30	.67	.27	.50	1.30	.20		800	2.5	24.0
Bakery waste, dehy	10.8	.27	.10	.33	.18	.41	.13	.25		1682	11.3	1.2
Barley	11.3	.41	.11	.35	.20	.48	.06	.35		1322	1.9	5.0
Beet pulp	8.6	.52	.10	.38	.07	.13	.70	.10		1134	.8	18.2
Blood meal, flash-dried	87.6	7.56	1.06	4.07	.95	2.15	.21	.21		886	1.6	1.0
Blood meal, spray-dried	88.8	7.45	1.48	3.78	.99	2.03	.41	.30	.28	1338	1.3	1.0
Canola meal	35.6	2.08	.45	1.59	.74	1.65	.63	1.01	.21	1200	3.5	11.1
Corn distillers grain w / sol., dehy	27.7	.62	.25	.94	.50	1.02	.20	.77	.59	1282	8.4	9.1
Corn distiller's dried grain	24.8	.74	.20	.62	.43	.71	.10	.40		1234	7.9	11.9
Corn gluten feed	21.5	.63	.07	.74	.35	.81	.22	.83	.49	1184	3.0	6.8
Corn, high lysine	10.1	.42	.11	.37	.17	.37	.03	.28	.04	1560	4.0	3.7
Corn, high oil	8.3	.29	.07	.30	.19	.40	.03	.28	.04	1608	6.5	2.3
Corn, hominy feed	10.3	.38	.10	.40	.18	.36	.05	.43	.06	1459	6.7	5.0
Corn, yellow	8.3	.26	.06	.29	.17	.36	.03	.28	.04	1555	3.9	2.3
DL-methionine	—	—	—	—	99.0	99.0	—	—	—	—	—	—
Fats / oils												
Beef tallow	—	—	—	—	—	—	—	—	—	3491	100	—
Choice white grease	—	—	—	—	—	—	—	—	—	3616	100	—
Poultry fat	—	—	—	—	—	—	—	—	—	3718	100	—
Restaurant grease	—	—	—	—	—	—	—	—	—	3730	100	—
Soybean oil	—	—	—	—	—	—	—	—	—	3818	100	—
Fish meal, menhaden	62.9	4.81	.74	2.64	1.77	2.34	5.21	3.04	2.86	1527	9.4	.9
L-Lysine HCl	95.8	78.0	—	—	—	—	—	—	—	—	—	—
L-Tryptophan	—	—	98.0	—	—	—	—	—	—	—	—	—
L-Threonine	—	—	—	99.0	—	—	—	—	—	—	—	—
Meat and bone meal, 50% CP	51.5	2.51	.28	1.59	.68	1.18	9.99	4.98	4.48	1011	10.9	2.4
Meat meal, 55% CP	54.0	3.07	.35	1.97	.80	1.40	7.69	3.88		1180	12.0	2.3
Millet, proso	11.1	.23	.16	.40	.31	.49	.03	.31		1340	3.5	6.1
Milo, grain sorghum	9.2	.22	.10	.31	.17	.34	.03	.29	.06	1518	2.9	2.2
Molasses, beet	6.6	—	—	—	—	—	.12	.03		1080	.2	0
Molasses, cane	4.4	—	—	—	—	—	.77	.08		909	.1	0
Oats	11.5	.40	.14	.44	.22	.58	.07	.31	.07	1232	4.7	10.7
Oats, high lysine	12.0	.50	.16	.44	.18	.40	.08	.30		1212	4.1	11.5
Oat groats	13.9	.48	.18	.44	.20	.42	.08	.41	.05	1575	6.2	2.5
Plasma proteins, spray-dried	78.0	6.84	1.36	4.72	.75	3.38	.15	1.71			2.0	.2
Rye	11.8	.38	.12	.32	.17	.36	.06	.33		1390	1.6	2.2
Skim milk, dried	34.6	2.86	.51	1.62	.92	1.22	1.31	1.00	.91	1689	.9	.2
Soy protein concentrate	64.0	4.20	.90	2.80	.90	1.90	.35	.81		1591	3.0	3.5
Soy protein isolate	85.8	5.26	1.08	3.17	1.01	2.20	.15	.65		1618	.6	.4
Soybeans, full-fat, cooked	35.2	2.22	.48	1.41	.53	1.08	.25	.59		1677	18.0	5.2
Soybean meal, dehulled	46.5	2.91	.62	1.85	.67	1.37	.34	.69	.16	1536	3.0	3.4
Soybean meal, solvent	44.0	2.83	.61	1.73	.61	1.31	.32	.65	.20	1445	1.5	7.3
Sunflower meal, 42% CP	42.2	1.20	.44	1.33	.82	1.48	.37	1.01		1243	2.9	15.8
Triticale	12.5	.39	.14	.36	.20	.46	.05	.33	.15	1445	1.8	4.0
Wheat bran	15.7	.64	.22	.52	.25	.58	.16	1.20	.35	1034	4.0	10.0
Wheat, hard	13.5	.34	.15	.37	.20	.49	.06	.37	.19	1459	2.0	2.6
Wheat middlings, <9.5% fiber	15.9	.57	.20	.51	.26	.58	.12	.93	.38	1375	4.2	7.8
Whey, dried	12.1	.90	.18	.72	.17	.42	.75	.72	.70	1450	.9	.2

Conversion Factors

Units (a	x	Multiplied by the factor below equals b	=	Units c) (c	x	Multiplied by the factor below equals d	=	Units e)
lb		453.6		g		.0022		lb
lb		.4536		kg		2.205		lb
kg		1,000		g		.001		kg
kg		1,000,000		mg		.000001		kg
g		1,000		mg		.001		g
g		1,000,000		μg		.000001		g
mg		1,000		μg		.001		mg
mg/kg		.0001		%		10,000		mg/kg
ppm		.0001		%		10,000		ppm
mg/g		453.6		mg/lb		.0022		mg/g
mg/lb		2.2		ppm		.4536		mg/lb
mg/lb		2		g/ton		.5		mg/lb
mg/g		1,000		ppm		.001		mg/g
mg/kg		1.0		ppm		1.0		mg/kg
g/ton		1.1		ppm		.907		g/ton
Mcal/lb		1000		kcal/lb		.001		Mcal/lb

Abbreviations and Symbols

Ca	calcium
CP	crude protein
g	grams
IU	international unit
Mcal	megacalorie
ME	metabolizable energy
mg	milligrams
ppm	parts per million
P	phosphorus
>	greater than
<	less than

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Additional Information Sources

Item	Available from
Swine Nutrition (ISBN 0-409-90095-8)	CRC Press, Inc 2000 Corporate Blvd., N.W. Boca Raton, FL 33431
Pork Industry Handbook	Media Distribution Center 301 South 2nd Street Lafayette, IN 47901-1232
Alfalfa in Swine Diets (G117) Mixing Quality Pig Feed (G892) Full-Fat Soybeans for Pigs (G994) Weaned Pig Management and Nutrition (G821) Conducting Pig Feed Trials on the Farm (EC270) Altering Swine Manure by Diet Modification (G99-1390) Nebraska Swine Reports	Local Extension Offices in Nebraska or: Bulletins P.O. Box 830918 Lincoln, NE 68583-0918 http://www.ianr.unl.edu/pubs/
NRC Nutrient Requirements of Swine (ISBN 0-309-05993-3)	National Academy Press 2101 Constitution Avenue, NW Lockbox 285 Washington, DC 20055 http://www.nap.edu/bookstore
Nontraditional Feed Sources for Use in Swine Production (ISBN 0-409-90190-3)	Butterworth Publishers 80 Montvale Avenue Stoneham, MA 02180
Diseases of Swine (ISBN 0-8138-0338-1)	Iowa State University Ames, Iowa 50014 http://www.isupress.edu
Swine Production and Nutrition (ISBN 0-87055-450-6)	AVI Publishing Company, Inc Westport, Connecticut

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