General Nutrition Principles for Swine

Table of Contents

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Introduction

Efficient and profitable swine production depends upon an understanding of the concepts of genetics, environment, herd health, management and nutrition. These factors interact with each other, and their net output determines the level of production and profitability. Feed represents 60 to 75 percent of the total cost of pork production. Therefore, amino acids, carbohydrates, vitamins, minerals, and water must be provided and balanced to meet the pig's requirements. Thus, a thorough knowledge of the principles of swine nutrition is essential in order to maintain a profitable swine enterprise.

Improvements in production have led to changes in nutrient recommendations in order to maximize performance. These requirements are continuously changing and this publication has been divided into six sections so it can be revised periodically to keep up with the latest developments and changes in technology. Furthermore, research summaries and additional information may be found by accessing our internet site at www.oznet.ksu.edu/dp_ansi/welcome.htm. The purpose of these publications is to provide the latest recommended nutrient allowances and answer some of the more frequently asked questions concerning swine nutrition. In some instances it may be advisable to seek professional nutrition advice for additional information. Suggestions made in this guide may not be applicable to swine production in other regions of the United States or in other countries.

Why is there variation in nutrient recommendations among universities?

There is some variation among the land grant universities in nutrient level recommendations. The main reason for the differences is the amount of added nutrients beyond the National Research Council (NRC) minimum requirement. The NRC periodically reviews and publishes estimates of the nutritional requirements for swine. These requirements are based on pigs fed under experimental conditions with normal health and performance. Many of the requirements are based on feeding a corn-soybean meal diet. In this publication, the nutrient recommendations have been increased beyond the NRC levels to add a margin of safety for each of the essential nutrients. In addition, with improved record keeping programs, there are data to suggest that feed intake in swine production systems may not be as great as previously estimated. Although a pig's requirement for a specific nutrient may be the same, if it is not eating the estimated amount, the nutrient density of the diet must be increased in order to meet its daily nutrient requirement. Our purpose is to reduce the risk of nutrient deficiencies that might occur because of differences in ingredient quality, genetics, health, environment, and performance on individual farms, and provide a margin of safety in a cost effective manner.

What are some of the factors that influence nutrient requirements?

Several factors affect a pig's requirement for a specific nutrient. Requirements are influenced by a combination of growth potential and feed intake, which will require changing the concentration of the nutrient in the diet to meet the pig's requirement on an amount-per-day basis. Some of these factors are:

- Environment (temperature, weather, housing and competition for feed)
- Breed, sex, and genetic background of pigs
- Health status of the herd
- Presence of molds, toxins, or inhibitors in the diet
- Availability and absorption of dietary nutrients
- Variability of nutrient content and availability in the feed
- Level of feed additives or growth promotants
- Energy concentration of the diet
- Level of feeding, such as limit feeding versus ad libitum

Environmental temperatures and housing conditions play an important role in determining the pig's nutrient needs for maintenance. Pigs housed in outside dirt lots are exposed to greater temperature changes than those housed in confinement facilities and may have greater maintenance needs. In addition, research has indicated that pigs of different sex, breeds, or genetic background may have different capacities for production, thus different nutrient requirements. It is reasonable to expect that a sow weaning 27 pigs per year would have a higher requirement than one weaning only 15 pigs per year. Feed quality, including processing methods; nutrient availability and variability; and the presence of molds, toxins, or anti-nutritional factors will influence pig performance and feed costs. Herd health status and the presence and level of feed additives or growth promotants will also alter nutrient utilization. Finally, factors affecting feed intake such as level of feeding or energy density of the diet will alter requirements. In general, as measures are taken to increase production (i.e., growth rate or pigs per sow per year, etc.), increasing the nutrient fortification of the diet may be required to meet these challenges in pig production. Tables 1 and 2 list typical growth rates, carcass traits, and sow performance, as well as goals for future production values. As an industry, we need to be aware of our past as well as keep an eye on the future in order to remain competitive and profitable.

Table 1. Pig Performance Standards[a].

	Percentile	
	50th	90th
Nursery Performance		
ADG, lb	.85	1.03
ADFI, lb	1.42	1.85
F/G	1.71	1.44
Grow-finish performance		
ADG, lb	1.61	1.80
ADFI, lb	5.05	5.85
F/G	3.15	2.80

[a] 1995 Pig Champ Database Summary.

Table 2. Average Overall Herd Performance[a].

	Percentile	
	50th	90th
Avg nonproductive days	70.5	45.4
Farrowing rate	80.1	88.9
Avg pigs born live	10.2	11.0
Litters/female/year	2.09	2.34
Pigs weaned/litter	9.0	9.8
Adjusted 21-day litter, wt, lb	125.2	142.5
Pigs weaned/female/year	18.6	21.8

[a] 1995 Pig Champ Database Summary.

Energy

Carbohydrates and fats in the diet supply most of the pig's caloric needs. Today, energy requirements are expressed as kilocalories (kcal) of digestible (DE), metabolizable energy (ME), or net energy (NE) per pound of feed. Digestible energy is defined as the amount of energy in the feed minus the amount of energy lost in the feces, whereas ME is defined as the amount of energy in the feed minus the energy lost in the feces and urine. Net energy is defined as the amount of energy in the feed minus the energy lost in feces, urine, and the heat produced through digestive and metabolic processes (heat increment). Digestible and metabolizable energy are the most frequently used terms to describe energy values for swine; however, as more data becomes available on the heat increment of feed ingredients for swine, NE may become a more precise method to evaluate energy needs of swine.

Energy sources for swine are the cereal grains: corn, milo, wheat, barley, and their by-products. In addition, fat, which contains 2.25 times the amount of energy as cereal grains, is often used to increase the energy density of swine diets. Most common cereal grains and fats are quite palatable and digestible. However, cereal by-products tend to be more variable; therefore, their use in swine diets may be limited. Although cereal grains will provide carbohydrates to meet the pig's energy needs, they must be supplemented with amino acids (protein), vitamins, and minerals to meet the pig's requirements for these nutrients. In the past, when formulating diets with the common cereal grains we were not as concerned with energy concentrations because the pig will often eat to meet its energy requirement. However, to make accurate decisions on the potential use of alternative energy sources, it is becoming more important to know dietary energy concentrations to evaluate possible changes in feed efficiency. Furthermore, when low-energy feeds are used, pigs are limit-fed (sows and gilts), or external factors limit feed intake, dietary energy levels must be determined to ensure adequate intake.

Are corn and milo (sorghum) comparable?

Both grains are excellent energy sources in swine diets. In Kansas, however, milo is often a cheaper source of energy and produces more economical gains. Because the energy content of corn is slightly higher than that of milo, feed efficiency of pigs fed corn diets will be slightly better than that of pigs fed milo, but average daily gains will be the same. A general recommendation for swine diets is to replace corn with milo on a pound-for-pound basis or on a lysine basis. One disadvantage of milo is that it can be more variable in nutrient content than corn because of growing conditions. In addition, because a milo kernel is smaller and harder than a corn kernel, fine grinding (⅛- or 5⁄32-inch screen) or rolling is suggested for best utilization.

What other energy feeds can be fed to pigs?

Wheat. Wheat is an excellent feed grain for swine, but usually is not competitively priced with milo or corn. Wheat can replace all or part of the corn or milo in a swine diet without affecting performance. Because wheat has slightly more lysine and phosphorus than corn and milo, the amount of soybean meal and supplemental phosphorus can be reduced in the diet. Research has shown that soft red winter wheat is comparable in feeding value to hard red winter wheat for finishing pigs. Because wheat tends to flour when processed, it should be coarsely ground (3⁄16-inch screen) or rolled. If ground too finely, feed intake may be decreased and performance lowered.

Barley. Barley also contains more lysine than milo or corn. However, it contains less energy and more fiber. Therefore, pigs fed barley-based diets will tend to have 5 to 10 percent poorer feed efficiency. Fine grinding (600 to 700 microns) of barley diets improves the feeding value for growing/finishing pigs, but when energy intake is critical, barley diets are not recommended.

Oats. Oats also have more lysine than either milo or corn, but again their high fiber content limits their application in swine diets. Oats should not exceed 30 percent of the diet for growing/finishing pigs. Because of the high fiber content of oats and barley, they may be best utilized in sow gestation diets, if economically priced.

High-lysine corn. Opaque-2 corn, commonly called high-lysine corn, is a variety of corn that has been selected for improved protein quality. High-lysine corn is higher than regular corn in all essential amino acids except leucine. Because the lysine content is higher than that of normal corn (.38 versus .25 percent), diets should be formulated on a lysine basis. The major disadvantages of high-lysine corn are reduced yields and decreased kernel durability.

Genetically Engineered Grains. Advances in genetic engineering have resulted in the development of several cultivars of different grains with added nutritional value. Currently, high-oil corn is one of the more widely available engineered grains for use in swine diets. As the name implies, high-oil corn typically contains more oil (6.5 versus 3.5 percent) than conventional corn which provides approximately 70 kcal/pounds more energy. Furthermore, high-oil corn has been shown to have more lysine than conventional corn (.30 versus .26 percent) which can reduce the amount of soybean meal needed in the diet. As a result, a typical finishing diet with high-oil corn would provide approximately 50 pounds of added fat and replace 20 pounds of soybean meal. Recent research suggests that the nutrients in high-oil corn are equally available as in conventional corn. Therefore, under typical pricing situations, high-oil corn is worth approximately $.20 to .25/bushel more than conventional corn. This premium will change based on changes in fat, corn and soybean meal prices. With time, new varieties of engineered grains with other improved quality traits will become available. These grains will need to be evaluated as they are introduced. In addition, there will be a need for greater emphasis on quality control and analytical procedures to verify nutrient composition.

The amount of feed per unit of gain is not the most important factor in formulating swine diets. Cost per unit of gain is more important; therefore, it is necessary to use the most economical energy sources in swine diets. The relative feeding values listed in Table 3 can be used to calculate the most economical energy source. For example, if corn costs 5.0 cents per pound, milo is a better value when it costs less than 4.8 (5.0×96 percent) cents per pound.

What feed ingredients should be fed in limited amounts?

There is no perfect feed ingredient that can be fed to pigs by itself. Some feeds, if added to the diets in excess amounts, will decrease performance. Some less commonly fed feedstuffs, such and millet and rye, should not exceed the recommended levels shown on Table 4.

Should fat be added to swine diets?

Fats and oils such as choice white grease, beef tallow, corn oil, and soybean oil contain about 2.25 times as much metabolizable energy as most of the cereal grains. Research indicates that the addition of 3 to 5 percent fat to growing–finishing swine diets will improve feed conversion and often average daily gain. However, adding fat to ad libitum fed diets generally tends to increase backfat thickness. A reduction in the amount of dust will be evident and wear on mixing equipment and augers will be reduced with 2 to 3 percent added fat. Addition of fat above 5 percent will further improve feed conversion, but physical handling problems such as bridging in the feeders and caking in the mixer may limit the use of these higher levels. Diets containing fat may become rancid during prolonged storage or when feed is exposed to high temperatures. Therefore, an antioxidant such as ethoxyquin, BHT, or BHA may need to be added to fat before mixing it into the rations.

Adding fat to swine diets is a matter of economics. Fat additions will usually increase the cost of the diet, which must be offset by an

Table 3. Feeding Value of Energy Feeds Compared to Corn.

Feedstuff	Relative value compared to corn, %
Corn	100
Alfalfa meal, dehydrated	65 to 75
Barley	90 to 95
High lysine corn	110 to 115
Millet	90 to 95
Milo	96
Oats	70 to 80
Oat groats	110 to 115
Rye	80 to 85
Fat and oil	210 to 220
Triticale	95 to 105
Wheat	105 to 107
Wheat middlings	90 to 95
Whey, dried	100 to 110

Table 4. Typical Maximum Usage Rates for Common Energy Sources[a].

	Maximum recommended percent of complete diet[b]				
Ingredient	Starter	Grow-finish	Gestation	Lactation	Limitation
Alfalfa meal, dehy	0	10	25	0	High fiber
Bakery waste, dehy	25	*	*	*	High salt
Barley	25	*	*	25	High fiber
Beet pulp	0	5	50	0	High fiber
Corn	*	*	*	*	None
Corn distillers grains w/solubles, dehy	5	15	40	5	Amino acid balance
Corn gluten feed	5	10	*	5	High fiber
Corn, hominy feed	0	60	60	60	Amino acid balance
Fat/oils	8	5	5	5	Feed handling
Millet	10	40	40	10	Difficult processing
Molasses	0	5	10	5	Low energy
Oats	5	20	50	0	High fiber
Oats groats	*	*	*	*	None
Rye[c]	0	25	25	10	Variability
Sorghum (milo)	*	*	*	*	None
Triticale[c]	10	*	*	50	Variability
Wheat bran	0	10	30	10	High fiber
Wheat, hard	*	*	*	*	None
Wheat middlings	5	25	*	5	High fiber
Wheat shorts	10	40	40	40	Variability
Whey, dried	40	15	5	5	High lactose

[a] Adapted from the NPPC Feed Purchasing Manual, Nebraska and South Dakota Swine Nutrition Guide, and Swine Nutrition Guide from the Prairie Swine Centre.

[b] Percentages suggest maximum allowable inclusion rates for energy sources. Economics and pig performance standards must be considered for actual inclusion rates. Most or all of the nutritional limitations can be overcome with proper formulation.

[c] Must be free of ergot.

* Denotes no nutritional limitation in a diet balanced for essential amino acids, energy, minerals, and vitamins.

increase in pig performance. Several commercial supplements and complete feeds contain added fat. New commercial products that contain dried fat may reduce part of the mechanical problems of adding liquid fat on the farm, but the economic feasibility of using these products must be evaluated. Fat products that have limestone as the carrier should be avoided, because the calcium will decrease the digestibility of the fat.

Research with sows suggests that feeding a diet with 5 percent added fat at a rate of 5 pounds/day for 10 days before farrowing has the potential to improve pig survivability if preweaning survival is below 80 percent. The reasons for the increase in survival rate appear to be increases in milk yield and milk fat content.

The potential benefits of fat addition must be evaluated in terms of economic considerations. When calculating what price you can pay for adding fat to a swine diet, the following equation can be used:

$$\frac{\text{New Cost} - \text{Old Cost}}{\text{New Cost}} \times 100 < \%\ \text{improvement in efficiency needed to offset added diet costs}$$

For example, if adding fat will increase diet cost by 5 percent, you must get at least a 5 percent improvement in feed efficiency before it is economical. It is important to note that this equation does not take into account changes in carcass characteristics or average daily gain. Fat may be added in summer diets to increase the energy density of the feed to offset low feed intake due to high temperatures. Feed efficiency is usually improved 2 percent for each 1 percent increment of added fat in growing–finishing pig diets.

Are there differences in fat sources?

Recent research has shown that not all fat sources give similar improvements in pig performance, especially for baby pigs. This may be a result of the fat source's fatty acid profile or impurities from the rendering process. In general, fat sources such as soybean oil and choice white grease are considered higher quality than tallow and yellow grease. Evidence indicates that blends of soybean oil and coconut oil support excellent performance in baby pigs. Waste cooking oils may be utilized in swine diets but should also be checked for quality. Cooking oils often contain high levels of free fatty acids which impair feed intake and increase corrosion of equipment. Fat sources of questionable quality should be analyzed for moisture, impurities, and unsaponafiable material (MIU), as well as total and free fatty acids. Moisture should not exceed 1 percent, impurities .5 percent, unsaponifiable material 1 percent, and total MIU 2.5 percent. Total fatty acids should be at least 90 percent while free fatty acids should be no greater than 15 percent. In addition, initial peroxide value provides an indication of rancidity potential. The peroxide value should be below 5 meq.

What is the feeding value of low test weight or weather damaged grains?

Under adverse weather conditions, such as drought, floods, and early frosts, low test weight, or sprout-damaged grain may be available for use in swine diets. As the degree of sprout damage increases or test weight decreases, the energy content of the grain is decreased. Therefore, the pig will need to eat more feed to meet its energy requirement. Although average daily gain will usually not be affected, feed efficiency will become poorer. Research has shown that this occurs when milo drops below 45 pounds per bushel test weight and wheat is below 50 pounds test weight. Furthermore, milo with up to 40 percent sprout damage can be effectively utilized by growing–finishing pigs. When the test weight of milo and wheat drop below 45 and 50 pounds, respectively, or there is more than 40 percent sprout damage, average daily gain will begin to be affected. Blending low test weight or sprout-damaged grain (up to 50 percent) with normal grain is an effective way to utilize weather-damaged grain. It is extremely important to recalibrate volumetric mixing equipment when feeding low test weight grains. Probably the biggest disadvantage to weather damaged grain is the increased potential for mold or aflatoxin contamination because of high moisture content. Therefore, weather damaged grains should always be screened for molds and aflatoxin and, if contaminated, these grains should not be fed to starter pigs or the breeding herd. If contaminated grains are going to be used, they should be blended with normal grain and only fed to growing-finishing pigs in limited amounts. Several compounds such as bentonite clay and alumniosilicates have been shown to improve pig performance when mold-contaminated grains are fed.

What are mycotoxins?

Mycotoxins are compounds produced by molds that when consumed by animals or humans will cause a toxicity. Not all molds produce mycotoxins and molds that do produce mycotoxins may only produce them under certain conditions. The type of clinical signs and the degree of toxicity exhibited by animals consuming mycotoxin contaminated grain will depend on the type and amount of mycotoxin in the feed grain and the class and species of animal. A listing of some of the more common mycotoxins and their clinical effects on swine is listed in Table 5. In general, young animals and breeding animals are more susceptible to the effects of mycotoxins. Although molds can produce many different mycotoxins, the two most commonly detected mycotoxins in wheat, milo, and corn in the Midwest are vomitoxin and zearalenone.

What is vomitoxin and what effect does it have on swine?

As the name of the toxin implies, vomitoxin can cause vomiting in pigs if consumed in large enough quantities. However, the most common signs in pigs consuming vomitoxin-contaminated feeds are feed refusal and decreased feed efficiency. The feed refusal results in reduced average daily gain. Vomitoxin adversely affects the function of many of the major organs of the body such as the liver and brain. This results in decreased nutrient utilization and feed efficiency. Thus, vomitoxin has the greatest detriment to performance in young, rapidly growing nursery age pigs. Vomitoxin has also been reported to cause reproductive problems in sows.

What is zearalenone and what effect does it have on swine?

Zearalenone is a compound that mimics the effects of the hormone estrogen. Thus, most of the effects of zearalenone are confined to the reproductive tract of swine. Gilts and sows consuming zearalenone-contaminated grain will exhibit vulvar reddening and swelling. Vaginal and rectal prolapses are a frequent result of zearalenone consumption in swine. They also will exhibit frequent, irregular estrous cycles and litter size may be drastically decreased. Young boars will undergo a feminizing effect, with atrophy of the testes and enlargement of the mammary gland. Research has indicated that normal reproductive function resumes after the removal of zearalenone-contaminated grain from the diet. There is little evidence to indicate negative effects on growth performance in growing and finishing swine.

Can mycotoxins be a problem in grain by-products?

Yes, many times grain by-products contain the hulls or the outer covering of the grain where mycotoxin concentration is greatest. Mycotoxin concentrations may actually be higher than in the original lot of grain. For example, wheat midds consist of the parts of the wheat kernel where most of the mycotoxins are attached. The production of wheat midds actually concentrates the level of mycotoxins. Careful consideration and testing for mycotoxins should be undertaken when grain by-products are included in swine diets. Other possible problems could arise from the use of mycotoxin contaminated straw for gestating sows. Gestating sows on limit fed diets may consume large quantities of contaminated straw resulting in a toxicity. Mycotoxin contaminated straw should not be a problem for finishing pigs with access to clean feed.

What steps should be taken if mycotoxin contaminated grain is suspected?

The first step is to obtain a 1- to 2-pound representative sample of grain and have it analyzed for the presence of mycotoxins. The sample should be transported to the laboratory in a paper sack. The paper sack prevents the condensation of moisture and the further proliferation of mold growth. An excellent laboratory for the detection of mycotoxins is the Veterinary Diagnostic Laboratory at North Dakota State University (Table 12). Several other state and private laboratories also test for the presence of mycotoxins.

What are some recommended guidelines for feeding mycotoxin-infected grains?

The optimum solution is to buy clean grain for swine and feed the contaminated grain to cattle. Feeder cattle should be able to safely consume levels five to 10 times higher than swine. If contaminated grain must be fed, the following table lists some maximum recommended levels in swine diets for various mycotoxins (Table 5).

Protein and Amino Acids

The pig does not have a specific requirement for crude protein, but rather for the individual components or sub-units that make up protein, called amino acids. Proteins are made up of several different combinations of approximately 20 different amino acids. During the process of digestion, proteins are broken down into individual amino acids that are absorbed into the bloodstream. The amino acids are then incorporated into new protein molecules. When formulating diets with commonly available grains and protein sources, the level of crude protein typically used to describe the diet usually will contain adequate amounts of amino acids to meet the pig's requirement. However, it is important to remember that this is not always true when using synthetic amino acids and alternative or by-product feed ingredients, and that the dietary levels of amino acids should always be checked. It is becoming increasingly important to specify lysine levels when formulating and evaluating swine diets.

If a diet is inadequate in any essential amino acid, protein synthesis cannot proceed beyond the rate at which that amino acid is available. This is called a limiting amino acid. Another way of describing a limiting amino acid is thinking of protein as a rain barrel and the amino acids as the individual staves making up the barrel. If one stave (amino acid) is shorter than the others (limiting), the barrel can only be filled to the level of the shortest stave. In the pig, a deficiency of one or more amino acids will result in depressed growth rate, poor feed conversion, unthriftiness, or reduced reproductive performance. Therefore, protein quality can be defined as how closely the

Table 5. Clinical Guide to Mycotoxins in Swine[a].

Toxin	Category of swine	Dietary level[b]	Clinical effects
Aflatoxins	Growing/finishing	<100 ppb	No clinical effect; residues in liver
		200–400 ppb	Reduced growth and feed efficiency; possible immuno-suppression
		400–800 ppb	Microscopic liver lesions, cholangio-hepatitis; increase serum liver enzymes; immuno-suppression
		800–1200 ppb	Reduced growth; decreased feed consumption; rough hair coat; icterus; hypoproteinemia
		1200–2000 ppb	Icterus; coagulopathy; depression; anorexia; some deaths
		>2000 ppb	Acute hepatosis and coagulopathy; deaths in 3–10 days
	Brood sows/gilts	500–750 ppb	No effect on conception; deliver normal piglets that grow slowly due to aflatoxin in milk
Ochratoxin and citrinin	Finishing	200 ppb	Milk renal lesions seen at slaughter; reduced weight gain
		1000 ppb	Polydipsia; reduced growth; azotemia and glycosuria
		4000 ppb	Polyuria and polydipsia
	Sows/gilts	3–9 ppm	Normal pregnancy when fed first month
Trichothecenes	Growing/finishing		
T-2 toxin and DAS		1 ppm	No effect
		3 ppm	Decreased feed consumption
		10 ppm	Decreased feed consumption; oral/ dermal irritation; immuno-suppression
		20 ppm	Complete refusal, vomiting
Deoxynivalenol (vomitoxin)		1 ppm	No clinical effect, minimal reduction in feed consumption
		5–10 ppm	25–50% reduction in feed consumption
		20 ppm	Complete refusal
Zearalenone			
F-2 toxin	Prepuberal gilts	1–3 ppm	Estrogenic; vulvovaginitis, prolapse
	Cycling sows/gilts	3–10 ppm	Retained corpora lutea, anestrus, pseudopregnancy
	Pregnant sows	>30 ppm	Early embryonic death when fed 1–3 weeks postmating
Ergot	All swine	.1%[c]	Reduced gain
	Sows, last trimester	.3%	Reduced piglet birth weight; agalactia
	All swine	.3%	Gangrene
	All swine	3.0%	Decreased feed consumption
Fumonisins (estimated)	All swine	50–100 ppm	Acute pulmonary edema; hepatosis; impaired lymphoblastogenesis; decreased feed consumption

[a] Adapted from Mycotoxins, by G. D. Osweller in Diseases of Swine, 7th Ed.
[b] Estimated toxic concentrations are based on literature values.
[c] Concentration of ergot sclerotia in diet.

essential amino acids in the protein source come to meeting the pig's estimated requirement for those amino acids. The 10 essential amino acids that must be provided in swine diets are: lysine, threonine, tryptophan, methionine (and cystine), isoleucine, histidine, valine, arginine, and phenylalanine (and tyrosine). Most cereal grains are limiting in lysine, tryptophan, threonine, and methionine. Therefore, when evaluating feed ingredients, these amino acids, especially lysine, are most important in determining protein quality.

What are some other common sources of amino acids?

Protein sources are classified into two major categories: animal (tankage, meat and bone meal, fish meal, or spray-dried blood meal) and plant (soybean meal, cotton seed meal, or corn gluten meal). Soybean meal is usually the most economical source of high quality protein available to Kansas swine producers. It is the only plant protein that compares with animal protein in terms of quality of amino acid content and ratio and can be used as the only protein source in most swine diets. Therefore, there is no need to have both animal and plant protein sources in a swine diet, with the exception of starter diets, which should contain dried whey and (or) spray-dried blood products. Producers in Kansas and other states may have the choice of buying either 44 percent or 46.5 percent crude protein soybean meal. The primary difference is that 44 percent soybean meal is made by adding soy hulls to 46.5 percent soybean meal. In addition to the lower fiber content, transportation costs may favor buying the 46.5 percent soybean meal.

How can I determine the most economical protein source to use?

In order to determine the relative feeding value of alternative protein sources, it is important to compare the lysine level in the new protein source to soybean meal. The relative feeding values of some alternative protein sources are listed in Table 6. This can be utilized to determine the comparative economic value of the protein source as a partial or complete replacement to 44 percent soybean meal. These feeding values were calculated by dividing the lysine content of the feed ingredient by that of 44 percent soybean meal (2.85 percent lysine) and multiplying by 100 to put them on a percentage basis.

Assuming that 44 percent soybean meal can be purchased at $250 per ton, what would a ton of 46.5 percent soybean meal be worth? Because the lysine content of 46.5 percent soybean meal

Table 6. Alternative Amino Acid Sources.

Source	Protein %	Lysine %	Relative value as a lysine source, %
Plant proteins			
Soybean meal	44	2.85	100
Soybean meal	46.5	3.01	106
Soy protein concentrate	66	4.2	147
Soy protein isolate	92	5.2	182
Alfalfa meal	17	.80	28
Canola meal	38	2.27	80
Corn gluten meal	42.1	.78	27
Sunflower meal	45.5	1.68	60
Cottonseed meal	41	1.51	53
Potato protein	76	6.27	220
Wheat bran	15	.56	20
Wheat gluten, spray-dried	74	1.3	46
Wheat middlings	16	.68	24
Yeast, brewers dried	45	3.23	113
Animal proteins			
Animal plasma, spray-dried	70	6.5	228
Egg protein, spray-dried	48	3.3	116
Fish meal	60	4.75	167
Blood meal, spray-dried	86	8.02	281
Fish solubles, dried	54	1.73	61
Meat and bone meal	50	2.80	98
Skim milk, dried	33	2.54	89
Tankage	60	3.00	105
Whey, dried	12	.97	34

Table 7. Typical Maximum Usage Rates for Common Amino Acid Sources[a].

	Maximum recommended percent of complete diet[b]				
Ingredient	Starter	Grow-finish	Gestation	Lactation	Limitation
Alfalfa meal, dehy	0	10	25	0	High fiber
Animal plasma, spray-dried	*	*	*	*	None
Blood meal, spray-dried	3	5	5	5	Low isoleucine
Canola meal	0	15	15	15	Anti-nutrition factor
Corn distillers grains w/solubles, dehy	5	15	40	10	Amino acid balance
Corn gluten meal	10	30	*	10	Amino acid balance
Cottonseed meal	0	10	15	0	Low lysine
Egg protein, spray-dried	6	10	10	5	Anti-nutrition factor
Fish meal	20	6	6	6	"Fishy" pork
Meat and bone meal	5	5	10	5	High minerals
Meat meal	0	5	10	5	High minerals
Skim milk, spray-dried	*	*	*	*	None
Soy protein concentrate	*	*	*	*	None
Soy protein isolate	*	*	*	*	None
Soybean meal	*	*	*	*	None
Soybean, full-fat, heat-treated	*	*	*	*	Overheating
Sunflower meal	0	20	*	0	Low energy
Tankage	5	5	5	5	Quality
Yeast, brewers dried	5	10	10	10	Variability
Wheat gluten, spray-dried	10	*	*	*	Low lysine
Whey, dried	40	15	5	5	High lactose

[a] Adapted from the NPPC Feed Purchasing Manual, Nebraska and South Dakota Swine Nutrition Guide, and Swine Nutrition Guide from the Prairie Swine Centre.

[b] Percentages suggest maximum allowable inclusion rates for energy sources. Economics and pig performance standards must be considered for actual inclusion rates. Most or all of the nutritional limitations can be overcome with proper formulation.

* Denotes no nutritional limitation in a diet balanced for essential amino acids, energy, minerals and vitamins.

is 3.01 percent and 44 percent soybean meal has 2.85 percent lysine, 46.5 percent soybean meal has 106 percent the feeding value of 44 percent soybean meal (3.01/2.85 × 100 = 106%). Therefore, if 106 percent is multiplied by the cost of 44 percent soybean meal (106% × $250), 46.5 percent soybean meal is of greater value than 44 percent soybean meal if it costs less than $265 per ton.

At what levels can feed ingredients be substituted for soybean meal?

When substituting other protein sources for soybean meal, it is important to consider the maximum level at which the new feed ingredient can replace soybean meal without seriously affecting performance. Table 7 is a list of alternative protein sources that can be used in starter, growing–finishing, gestation, and lactation diets to replace all or part of the soybean meal. By using this table, you can determine the maximum replacement rate of the feed ingredient for soybean meal.

Can other alternative protein sources be fed to pigs?

This section lists some of the more common substitutes for soybean meal in swine diets. Very often, these feed ingredients may appear to be economical compared to soybean meal. However, there are often many "hidden" costs or disadvantages in using these feed ingredients that are not reflected by their price. These include storage costs, anti-nutritional factors, product variability, fiber content, spoilage, and under- or over-processing. These factors are especially problematic in "by-product" protein sources. Because by-product feed ingredients tend to vary more in composition, proper information regarding chemical composition is necessary to ensure optimum pig performance. Additional protein sources and recommended maximum inclusion rates for each stage of production are listed in Table 7.

Cottonseed Meal

Cottonseed meal ranks second in production compared to soybean meal. However, its use in swine diets is limited because of the deleterious effects produced by the residual free gossypol found in the pigment glands of the seed. Although fairly high in protein, cottonseed meal is low in lysine and tryptophan. It is recommended that cottonseed meal replace no more than 50 percent of the soybean meal or protein supplement in the diet. At this inclusion rate, it is unlikely that the total diet will contain over .01 percent free gossypol. Pig performance begins to be reduced at gossypol concentrations of .04 percent of the diet. Solvent extracted, gossypol-free cottonseed meal can be used to replace 75 percent of the protein source in growing–finishing diets when balanced on a lysine basis.

Canola Meal

Canola meal is the by-product of vegetable oil processing from canola. Because it is well adapted to cool season growing conditions, canola is produced primarily in Canada and the northern states. Its oil contains a high level of unsaturated fats, and production is expanding throughout the United States. Canola meal averages between 35 and 40 percent crude protein and has less lysine but more sulfur-containing amino acids than soybean meal. Some older varieties of canola (rapeseed) contain high levels of a toxic compound, glucosinolate, which effects thyroid functioning. However, new cultivars of low-glucosinolate rapeseed (< 1 mg/g) have been developed and are commonly referred to as canola meal to distinguish it from the older varieties of high-glucosinolate rapeseed. It is not advisable to feed meals from the cultivars of high glucosinolate rapeseed. Reduced palatability, high fiber, and low digestible energy have been causes of slightly poorer performance of pigs fed diets containing canola meal. Canola meal can be used to replace up to 50 percent of the protein from soybean meal in growing-finishing and sow diets without adversely affecting performance.

Sunflower Meal

Sunflower meal is produced by extraction of the oil from sunflower seeds. Because of its high fiber content (22 to 24 percent), it should be utilized in limited quantities in swine diets. Sunflower meal is relatively low in lysine yet high in sulfur-containing amino acids in comparison to soybean meal. Sunflower meal containing high levels of oil will produce soft pork because of the oil's unsaturated fatty acid content. It appears that sunflower meal may replace up to 25 percent of the protein in the diet for growing-finishing pigs.

Meat and Bone Meal

Meat packing by-products often are economically feasible to add to swine diets. In general, meat and bone meal is an excellent source of calcium and phosphorus. However, it is often very low in tryptophan and methionine. Since there is considerable variation in the type and quality of the raw materials used, there is potential for greater variation in the quality of meat and bone meal. Excessive heating during the processing of meat and bone meal may also decrease its digestibility and value as a protein source. Therefore, it is recommended that meat and bone meal should not exceed 25 percent of the protein supplement.

Spray-dried Blood Products

Spray-dried blood products have revolutionized nutritional programs for early-weaned pigs. Spray-dried animal plasma and spray-dried blood meal, by-products of blood obtained from swine and cattle processing plants, are the most exciting protein sources to become available to the swine industry in recent years. Previously, spray-dried animal plasma has been used as a supplement for cereal protein in bakery products as well as an emulsifying agent in meat products and pet foods. It is made up of the albumin, globin, and globulin fractions of blood and contains 68 percent protein and 6.9 percent lysine. The blood is collected in refrigerated tanks and prevented from coagulating by adding sodium phosphate. The plasma fraction is separated from the blood cells by centrifugation and stored at 25°F until the product is spray dried. This process consists of preheating (25 minutes at 200°F), spray-drying (1 to 2 minutes at 405°F), and evaporating of moisture (1 to 2 minutes at 200°F), resulting in a fine-grained powder. Spray-dried blood meal is processed similarly, except it contains the plasma and red blood cell fractions. Spray-dried red blood cells, a by-product of animal plasma production, appears to have similar nutritional value in starter diets as spray-dried blood meal.

When adding spray-dried blood products to starter diets, dietary methionine levels must be checked because these ingredients are low in methionine. Synthetic methionine should be added to starter diets containing either spray-dried animal plasma, blood meal, or red blood cells.

Spray-dried Wheat Gluten

Spray-dried wheat gluten is the protein fraction of wheat remaining after the starch has been extracted for use in human food products. Wheat gluten contains approximately the same crude protein content as spray-dried animal plasma (75 versus 68 percent, respectively) but it is extremely low in lysine (1.3 percent). Amino acid supplemented starter diets containing spray-dried wheat gluten provide similar growth performance as diets containing dried skim milk and may be more cost effective.

Soy Protein Concentrate

Soy protein concentrate contains approximately 65 to 70 percent protein and approximately 4.2 percent lysine. It is produced by removing the water soluble sugars, ash and other minor constituents from defatted soy flour by either an alcohol, dilute acid, or warm water extraction. All three of these systems are utilized in the feed industry, producing products similar in composition. Research results indicate that soy protein concentrate can effectively replace dried skim milk in starter pig diets. Furthermore, research suggests that pigs fed moist extruded soy protein concentrate may have greater average daily gain and better feed conversion than pigs fed soy protein concentrate.

Soy Protein Isolate

The highest concentrated soy protein source is the soy isolate. To produce a soy isolate, defatted soy flakes are insolublized by reducing the pH to 4.5 (isoelectric point). At this point, the isoelectric proteins are separated from the soluble materials. The process is similar to the acid extraction procedure described to produce soy protein concentrate. The removal of insoluble fibrous material by either decantation or centrifugation completes the protein isolation procedure. This final product can be spray-dried to give an isoelectric protein, or neutralized to pH 7.0 and dried to give the common soy protein isolate. During protein isolation, protein yield is decreased due to minor proteins remaining soluble. Soy protein isolate is also an effective replacement for dried skim milk in starter pigs diets.

Raw Soybeans

Raw soybeans, especially weather damaged or low test-weight beans, are often attractive alternatives to add to swine diets. However, raw soybeans contain high quantities of trypsin inhibitors, which block normal protein digestion in pigs. As the pig becomes older, its susceptibility to trypsin inhibitors decreases. Therefore, raw soybeans may be used in gestation diets (but not lactation) without adversely affecting performance. If raw soybeans are to be used in diets for young pigs, it is important to heat the beans to inactivate the trypsin inhibitors. New varieties of soybeans are under development in which one of the trypsin inhibitors (Kunitz inhibitor) have been genetically selected against, which would allow for greater use in growing pig diets. However, research shows that some heat treatment of low Kunitz inhibitor soybeans is required for maximum utilization.

What is the value of full-fat soybeans?

On-farm processing by roasting or extruding of raw soybeans, if done properly, results in excellent sources of protein. On-farm roasting or extruding yield “full-fat” soybeans, which, in some instances, are among the cheapest means of adding fat to swine diets. Because of the economic relationship between soy oil and soybean meal and the cost of other fat sources and incorporating them into your feed mill, it may be more economical to utilize full-fat soybeans instead of selling the beans and buying back soybean meal and oil. Because whole or full-fat soybeans have less protein and lysine than soybean meal (32 to 37 percent protein and 2.1 to 2.4 percent lysine), it is necessary to add 20 to 25 percent more whole soybeans than soybean meal to have a similar protein level in the diet. At the same time, this will supply approximately 3 percent added fat to the diet, which will improve feed efficiency approximately 3 to 5 percent. Whole soybeans have an approximate feeding value of 90 to 95 percent that of soybean meal. The following equation can be used to determine if feeding full-fat soybeans is economically justified:

$A = .86Y + .17Z - (S + C)$, where:
A = cost advantage per ton of full-fat product
Y = cost of one ton of 44 percent soybean meal
Z = cost of one ton of feed grade fat
S = cost of one ton of soybeans
C = cost of processing one ton of soybeans

If it is feasible to feed full-fat soybeans, A will be greater than zero.

What are the effects of excessive drying temperatures on protein?

Excessive heat will reduce the availability of the amino acids, particularly lysine, in feed ingredients. If your soybean meal or dried whey looks darker than usual or has a burnt smell, it is possible that the protein quality has been reduced.

Will synthetic amino acids improve protein quality?

Synthetic amino acids, if added properly, can reduce feed costs and maintain pig performance. Lysine and methionine are the two feed-grade amino acids most commonly added to swine diets. However, in the future, synthetic threonine and tryptophan may be available at prices low enough to add to swine diets. Research has demonstrated that supplemental lysine can reduce the amount of soybean meal needed in swine diets. Therefore, adding synthetic lysine can reduce the crude protein level of the diet without affecting performance. The most common source of synthetic lysine is L-lysine monohydrochloride, which is 78 percent lysine. In diets for pigs, 100 pounds of 44 percent crude protein soybean meal can be replaced by the addition of 3 pounds L-lysine HCl and 97 pounds grain per ton. If the 3 pounds L-lysine HCl and 97 pound grain are cheaper than 100 pounds of 44 percent crude protein soybean meal, the diet costs would be reduced by using supplemental lysine. However, the use of synthetic lysine is generally not advisable in gestation or lactation diets. Synthetic lysine has been shown to be poorly utilized in pigs fed only once a day (gestating sows) compared with pigs fed ad libitum. In lactation, adding synthetic lysine alone to the diet, decreases the amount of other amino acids relative to lysine. This results in deficiencies of other amino acids which will reduce litter weaning weights.

What is "amino acid balance" and "ideal protein"?

Protein sources vary greatly in quality and quantity. Protein quality is directly dependent on the content of the most limiting amino acid relative to the pig's requirement. If a diet is not balanced correctly, a shortage of one of the essential amino acids will reduce growth rate and performance. An amino acid imbalance may occur if a second limiting amino acid is added to a diet when the first limiting amino acid is still deficient. This will result in a reduction in feed intake and reduced pig performance. On the other hand, when a diet is balanced for the most limiting amino acid (usually lysine), other amino acids are usually in excess of the pig's requirement. Some commercial companies are using the concept of amino acid balance or ideal protein in their sales promotions. This refers to formulating a diet in which all amino acid levels are very similar to the pig's requirement without excesses. However, there is no scientific information to indicate that the excesses of amino acids that naturally occur in milo- or corn-soybean meal-based diets will have a detrimental effect on pig performance. However, the use of low protein, amino acid fortified diets may decrease nitrogen excretion in manure and the environment.

Are amino acid requirements different for maximum gain, feed efficiency, and carcass leanness?

Suggested amino acid recommendations are usually based on the amount of an amino acid required to maximize rate of gain. However, slightly higher levels of amino acids will further improve feed efficiency and carcass leanness. This is because the higher amino acid levels allow the animal to deposit greater amounts of lean tissue rather than fat. Because it takes less energy to deposit lean than fat, feed efficiency is improved. Slightly higher levels of amino acids may be economical to producers who market their hogs on a lean value system, where there is incentive for producing lean pork. Suggested dietary lysine concentrations based on a pig's fat free lean index are included in the factsheet, *Growing–Finishing Pig Recommendations,* MF2301.

Do barrows, gilts, and boars have the same requirements for amino acids?

On an amount-per-day basis, barrows and gilts require similar amounts of amino acids. However, because gilts typically consume ½ pound less feed per day than barrows, they may not eat enough to fully meet their requirements. Although sometimes difficult to accomplish on the farm, split-sex feeding may offer some feeding and marketing alternatives. Split-sex feeding involves sorting gilts from barrows and feeding each separate diets. Because gilts consume less feed than barrows, their diets can be fortified with extra amino acids for growth rate and feed efficiency as well as calcium and phosphorus for bone development, if they are going to be retained for the breeding herd. Marketing programs taking advantage of the better feed efficiency of gilts can also be utilized with split-sex feeding. In general, we typically recommend feeding gilts a diet containing .05 to .10 percent more lysine than the diet for barrows. Additional information and suggested lysine levels for producers who split-sex feed are listed in the factsheet, *Growing–Finishing Pig Recommendations,* MF2301.

How does lean growth potential affect amino acid requirements?

Increased selection for lean pork production has opened opportunities for further refinement of nutrient requirements based on genetic potential for protein deposition. It is intuitive that a lean, rapidly growing pig will have a higher amino acid requirement than a fat, slow growing pig. Therefore, suggested dietary lysine levels for pigs of different growth potential are listed in the factsheet, *Growing–Finishing Pig Recommendations*, MF2301.

How will high ambient temperatures affect my pigs?

High ambient temperatures result in many physiological changes in the pig. High temperatures will decrease feed intake which will in turn decrease average daily gain. However, this will frequently result in increased carcass leanness because of decreased energy intake. In the past, we have recommended to increase dietary lysine concentrations and possibly add fat (if economically justified) to offset the decreased nutrient intake. However, while research data has shown that this practice will improve growth performance, it will not increase performance to the same level as pigs housed in a thermoneutral environment. In theory, if a pig has decreased daily gain, its lysine requirement should decrease; however, if carcass leanness increases, the requirement should increase. Therefore, these two opposing factors could potentially nullify any need to adjust diets for warm weather. Therefore, during the summer months, it is advisable to provide drip cooling, or some other method to keep pigs cool. If diets are adjusted based on season, it is advised that they be increased no more than .05 percent in finishing diets. Further research is needed to help solve this dilemma.

What are digestible amino acids?

Although two protein sources may contain the same amounts of a certain amino acid, because of some difference in the chemical structure of the protein, processing method, or antinutritional factor, not all of that amino acid may be digested or available to the pig. This is especially true for certain by-product feed ingredients or feed ingredients that have been over-processed. More and more information about amino acid digestibility is being published for a variety of by-product feed ingredients, such as cottonseed meal, meat and bone meal and blood meal. If you are using a high percentage of these feed ingredients, you may want to consider balancing the diet on a digestible amino acid basis. Because of the limited information on digestible amino acid values in ingredients and requirements, we highly recommend professional guidance when working on a digestible amino acid basis. However, if you are using milo or corn and soybean meal, there is probably no need to worry about formulating on a digestible amino acid basis.

What is the difference between total, apparent, and true digestibilities?

Generally, the gross concentration of an amino acid in a feed ingredient is considered its "total" value. Measuring the amino acid intake versus difference from what is excreted at the end of the small intestine is generally referred to as an "apparent digestible" amino acid concentration. This procedure requires that the pigs be surgically cannulated at the end of the small intestine to collect the digesta samples. Finally, "true" digestibility values are calculated from apparent digestibility values by further determining the amount of endogenous amino acid loss via sloughed intestinal cells and digestive enzymes. Because of differences in the digestibility coefficients and potential confusion between expressing requirements as either total, apparent, or true digestibilities, again, it is highly recommended that you get professional guidance when working on a digestible amino acid basis.

Is calorie:protein ratio important?

A pig will adjust its feed intake to a certain extent to meet its energy requirement. Therefore, when the energy density of the diet increases, a pig will tend to eat less feed. Thus, in diets with added fat, it is important to increase the concentration of amino acids. By increasing the concentration of amino acids in the diet, the pig will consume approximately the same amount per day even though feed intake is less. Currently there is limited information on the optimum calorie:protein ratios for pigs. Factors such as feed intake, genetics, environment, and rate and composition of gain may affect the calorie:lysine ratio. General guidelines for amino acid fortifications as well as proposed calorie:lysine ratios are presented in the factsheet, *Growing–Finishing Pig Recommendations,* MF2301.

Minerals

Minerals constitute a small percentage of the swine diet, but their importance to the health and well-being of the pig cannot be over-emphasized. Minerals have been classified into two types; macrominerals and microminerals. Macrominerals (major minerals) that are commonly added to swine diets are calcium, phosphorus, sodium, and chlorine (magnesium and potassium are also required but are adequately supplied by grains). Microminerals (minor or trace minerals) of primary concern are zinc, copper, iron, manganese, iodine, selenium and chromium.

Functions of minerals are extremely diverse, ranging from structural functions in some tissues to a wide variety of regulatory functions. The increasing trend toward confinement rearing of pigs, without access to soil or forage, increases the importance of meeting dietary mineral requirements.

What other trace minerals may be important?

Other trace minerals have been shown to be essential for chicks or laboratory animals and may be required by swine. These include molybdenum, cobalt, fluorine, nickel, silicon, vanadium, tin and arsenic. Whether these elements will be of practical significance awaits further research. Most of them are believed to be present in adequate quantities in natural feed ingredients. However, the use of simpler swine diets with fewer ingredients may necessitate consideration of their importance in the future.

What occurs if high levels of minerals are fed?

Minerals should not be added haphazardly. The old adage, "if a little is good, more is better," is not true when adding minerals to swine diets. If minerals are added without reason, more harm than good can occur. All minerals have a toxic level.

Some minerals, particularly calcium, if added in excess will interfere with absorption of other nutrients. As an example, calcium interferes with zinc absorption and results in a skin disorder called parakeratosis. A combination of a high level of calcium (over 0.9 percent) and marginal zinc level can result in this condition. Never mix additional minerals with a commercial supplement, unless the need is specified on the tag.

Why are calcium and phosphorus important?

These two elements are important in skeletal structure development, but their presence in soft tissues is also vitally important. They both aid in blood clotting, muscle contraction, and energy metabolism. About 99 percent of the calcium and 80 percent of the phosphorus in the body are found in the skeleton and teeth. Therefore, deficiency of calcium and phosphorus will result in impaired bone mineralization, reduced bone strength, and poor growth. Young pigs with a deficiency of calcium and phosphorus will have clinical signs of rickets. Mature pigs eating a deficient diet will remove calcium and phosphorus from the bone (osteoporosis), decreasing bone strength. This can result in a condition called “Downer Sows” and can be prevented by proper diet formulation.

What are the major sources of calcium and phosphorus?

The ingredients used in swine diets vary widely in mineral content. Most cereal grains are particularly low in calcium. Phosphorus content of cereal grains is largely phytate phosphorus, which is poorly utilized by swine. Several researchers are currently evaluating the availability of phosphorus in cereal grains. A range of 8 to 60 percent of phosphorus availability has been reported in cereal grains, but for practical purposes, an availability of 30 percent is a reasonable estimate.

Feeds of animal origin, such as meat and bone meal, tankage, or fish meal, are quite high in calcium and available phosphorus. Thus, the level of supplemental calcium and phosphorus must be recalculated as feeds of animal origin replace soybean meal in the swine diet.

The standard ingredients for supplying supplemental calcium are limestone or oyster shell. Phosphorus is primarily supplied by dicalcium phosphate or monocalcium phosphate. Table 8 lists a number of feed ingredients that may be used to supply calcium and phosphorus. It should be noted that many of the sources supply both calcium and phosphorus, so the quantity of limestone in the diet must also be adjusted. It is extremely important to check the nutrient specifications of these mineral sources, because the level of calcium and phosphorus may be different from the above values.

What is phytate phosphorus?

Approximately 50 to 70 percent of the phosphorus contained in plant products is in a form that is unavailable to the pig. The unavailable form of phosphorus is called phytate phosphorus. As a result, swine diets generally contain large amounts of phytate phosphorus which is not digested and excreted in manure. Many swine diets are formulated on a “total” phosphorus basis, i.e., taking into account all of the phosphorus contained in the grain, protein source and mineral supplements. Total phosphorus requirements generally correspond to an available or digestible phosphorus requirement with simple milo- or corn-soybean meal based diets. However, because of the growing concern about phosphorus excretion into the environment, formulating on an available phosphorus basis would assist in minimizing excess phosphorus excretion, especially when using alternative or by-product ingredients. Because of the variation in phosphorus availability estimates in ingredients and the potential for use of phytase, an enzyme which helps breakdown phytate phosphorus, we encourage professional assistance with evaluating available phosphorus requirements.

What is phytase and should I add it to my swine diets?

Phytase is an enzyme that when added to swine diets increases the digestibility of phytate phosphorus. Increased digestibility of phytate phosphorus will reduce the need for expensive inorganic phosphorus supplementation and reduce phosphorus excretions by the pig. Current recommendations suggest that if phytase is

Table 8. Sources of Calcium and Phosphorus.

Source	Mineral %		Remarks
	Ca	P	
Ground limestone	38	0	Good availability, usually the cheapest source of Ca. May contain 35% Ca.
Dicalcium phosphate	21	18.5	Good availability, levels may vary.
Monocalcium phosphate	18	21	Good availability, levels may vary
Tricalcium phosphate	38	18	
Sodium tripolyphosphate	0	25	Usually a more expensive source of P.
Disodium phosphate	0	21	
Defluorinated rock phosphate	32	18	Availability varies.
Steamed bone meal	28	14	
Meat and bone meal	9.4	4.58	
Tankage	4.6	2.5	
Fish meal	5.2	2.88	

added to the diet, the total phosphorus concentration can be reduced by .10 percent without determintal effects on pig performance. Therefore, without an allowance for decreased phosphorus excretion in swine waste, the cost of the added phytase needs to be evaluated versus the cost of the phosphorus supplement.

How can I determine which is the cheapest source of phosphorus?

Phosphorus is the second most expensive nutrient and most expensive mineral added to swine diets. It is possible to reduce the total cost of a diet by evaluating the cost of the supplemental phosphorus. For example, if the cost of dicalcium phosphate (21 percent calcium, 18 percent phosphorus) is $20 per 100 pounds and monocalcium phosphate (18 percent calcium, 21 percent phosphorus) is $25 per 100 pounds, which is the cheapest source of phosphorus? The cost of phosphorus per pound is divided by the percentage of phosphorus to determine the cost per pound of actual phosphorus.

For example:

Dicalcium Phosphate
20¢/lb = $1.11/lb
18% phosphorus of actual phosphorus

Monocalcium Phosphate
25¢/lb = $1.19/lb
21% phosphorus of actual phosphorus

Therefore, the dical would be a cheaper source of phosphorus.

How should I adjust different phosphorus sources?

The amounts of calcium and phosphorus can vary in products commonly called “dical.” Therefore, producers need to know how to adjust the amount of dical and limestone in their swine diets. In the suggested diets in following chapters of this publication, 21 percent phosphorus “monocal” was used for formulation. In adjusting the amounts of monocal or dical and limestone to achieve the desired levels of calcium and phosphorus, the following example may be helpful:

1. The diet has 30 lb of monocal (21% P; 18% Ca) and 10 lb of limestone (38% Ca).
2. You can purchase 18% phosphorus and 21% Ca dical at a lower price per unit of phosphorus.
3. Determine phosphorus levels:
   a. 30 pounds of monocal × 21% = 6.3 pounds of phosphorus supplied by monocal.
   b. 6.3 lb ÷ 18% = 35 lb of dical (18% P) needed to replace 30 lb of monocal (21% P).
4. Determine calcium levels:
   a. 30 pounds of monocal × 18% = 5.4 pounds of calcium supplied by monocal.
   b. 35 pounds of dical × 21% = 7.35 pounds of calcium supplied by dical.
   c. Needed amount of limestone:
      7.35 pounds of Ca - 5.4 lb of Ca = 1.95 pounds of extra Ca.
      1.95 ÷ 38% Ca = 5.15 fewer pounds of limestone needed.
5. Results:
   30 pounds of monocal (21% P; 18% Ca) and 10 pounds of limestone can be substituted for 35 pounds of dical (18% P; 21% Ca) and 4.85 pounds of limestone.

What is the ideal calcium-phosphorus ratio?

The optimum levels of calcium and phosphorus for various ages of pigs are provided in the nutrient recommendations in the following chapters. For maximum performance, minimum dietary levels of each are necessary, as well as the correct ratio of one to the other. The desired ratio of 1.0 to 1.3 calcium to 1.0 total phosphorus in a grain soybean meal diet is preferred, although if the phosphorus level is adequate, a calcium:phosphorus ratio of 2:1 will not affect performance. However, recent research has shown that when using phytase, maintaining a narrow Ca:P ratio is important.

Do breeding stock need greater amounts of calcium and phosphorus?

Levels of calcium and phosphorus that are adequate for maximum gain in body weight are not necessarily sufficient for maximum bone development. Borderline deficiency may go unnoticed in the growing–finishing pig, but cause serious consequences in those pigs saved for breeding purposes. With split-sex feeding, replacement gilts can be fed higher levels of calcium and phosphorus for maximizing bone development than market hogs.

Swine producers have reported leg weaknesses and abnormalities that impair the breeding effectiveness of young replacement animals. Many of the leg problems can be attributed to structural unsoundness. However, inadequate dietary calcium and/or phosphorus can impair bone mineralization and result in weaker bones. Limit feeding replacement gilts the finishing diet, which may reduce calcium and phosphorus intakes, is not advisable.

What is the level of calcium in soybean meal?

Calcium carbonate, commonly called ground limestone, is routinely used to aid in improving the flowability of soybean meal during processing. In the past, a value of .20 to .25 percent calcium has been observed in soybean meal, however, this level has fluctuated from .20 to over .50 percent. Therefore, as part of a standard quality control program, calcium levels in soybean meal should be periodically checked to minimize potential problems. The suggested diets contained in this publication have been formulated with a .26 percent calcium value for soybean meal.

How much salt is needed?

Salt, a combination of sodium and chloride, must be adequate in all swine diets. Grains and plant protein supplements are low in sodium and chloride, but the needs of the growing–finishing pig can be met by adding .25 to .35 percent salt to the diet. When a diet deficient in salt is fed to growing pigs, depressed performance will be evident within a few weeks. Research has suggested .5 percent added salt is adequate for breeding stock. Even though dried whey and spray-dried blood products contain relatively high levels of salt and (or) sodium, recent research has demonstrated improved growth rates when salt is added in addition to these ingredients.

High levels of salt can be tolerated, if adequate drinking water is available. However, if water is restricted, as little as .2 percent dietary salt has resulted in toxicity symptoms.

Why is it necessary to give baby pigs supplemental iron?

The baby pig is born with a limited supply of iron, and because the sow's milk is also low in iron, supplemental iron is a must. The most commonly used sources of iron to prevent anemia in newborn pigs are injectable and oral products. Injectable iron is the preferred method of anemia prevention. An intramuscular injection of 200 mg of iron dextran given at 1 to 3 days of age will prevent the anemia problem. Because the concentration of iron sources may vary, it is important to evaluate products based on a cost/mg iron basis.

Is a second iron injection necessary?

Most producers will give an iron injection within the first 3 days of life. Need for a second injection depends on the amount of iron available to the baby pigs during the lactation period and how much was given in the first injection. The baby pigs can receive iron orally from consuming creep feed or sow feed or from the sow's feces. Over 90 percent of the injected iron from the initial treatment is utilized over the first 3 weeks. If less than 200 mg of iron is given in the first injection, a second iron shot may be needed. Need for a second injection also depends primarily on blood hemoglobin concentration, a rapid and reliable indicator of the iron status of the pig. Blood hemoglobin levels of 10 mg/100 ml or above indicate adequate iron status. Hemoglobin levels of 8 to 9 mg/100 ml indicate a borderline anemia condition, whereas a value of 7 or below indicates an anemic condition. If blood hemoglobin levels fall below the 10 mg/100 ml level, a second iron shot is advisable.

When giving iron injections to baby pigs, what is the best injection site?

For many years, swine producers have been giving iron injections in the ham. When iron injections are given in the ham, permanent staining of the meat may occur. Because ham is one of the higher value cuts of pork, it is highly recommended that iron injections be given in the neck. Additional information regarding iron and medication injection sites is contained in the National Pork Producer's Council Pork Quality Assurance Program.

Are chelated or complexed mineral products beneficial to pig performance?

A chelated or complexed mineral is bound to a compound that helps to stabilize the mineral. Many claims have been made for the benefit of chelated and complexed minerals. One is the greater physical stability, which reduces the tendency for trace minerals to segregate in the feed. Another advantage is for less oxidation of vitamins and minerals and greater availability. Recent research has shown that chelated minerals will be 0 to 15 percent more available which will decrease the potential concern for excess mineral excretion into the environment. However, their cost may be two to three times greater than those of nonchelated minerals. Therefore, the costs of chelated and complexed minerals must be examined before adding them to swine diets.

Should selenium be supplemented in Kansas swine diets?

The need for supplemental selenium is related to vitamin E intake. With decreased use of pasture as a source of vitamin E, artificial drying of grains that causes partial destruction of vitamin E and increase in the incidence of mulberry heart disease in Kansas swine herds, supplemental selenium has become more important. The amount that may be added to swine diets is regulated by the U.S. Food and Drug Administration and is limited to 0.3 ppm (.27 g/ton) for all pigs.

Do I need to add chromium to my swine diets?

Recently, the FDA has allowed the use of chromium in swine diets. Currently, chromium tripicolinate is the only form approved; however, other forms, such as chromium nicotinate and chromium-yeasts, are currently being evaluated. Some studies have observed increased percentage lean and reduced backfat thickness in finishing pigs fed added chromium while others have not. In addition, some studies have observed increased farrowing rate or number of pigs born to sows fed chromium in finishing and gestation and lactation. Because of the variation in response observed to added chromium, careful evaluation of the cost and potential benefit (possibly involving on-farm evaluation) need to be considered.

Table 9. Sources of Trace Minerals[a].

Mineral	Source	Mineral, %	Remarks
Iron	Ferrous sulfate	20.8–32.9	Excellent bioavailability
	Ferric ammonium citrate	16.5–18.5	Good bioavailability
	Ferrous fumarate	32.9	Good bioavailability
	Ferric chloride	20.7	Mediocre bioavailability
	Ferrous carbonate	40–43	Bioavailability varies
	Ferric oxide	57–61	Limited bioavailability
Copper	Cupric carbonate	57.5	
	Cupric chloride	37.3	
	Cupric hydroxide	65.1	
	Cupric oxide	75–80	Good to excellent bioavailability
	Cupric sulfate	25.2	Excellent bioavailability
Manganese	Manganese carbonate	47.8	
	Manganese chloride	27.8	
	Manganese oxide	60.0–60.6	All are good sources
	Manganese sulfate	27.0–28.4	
	Manganous sulfate	32.5	
Zinc	Zinc carbonate	56.0	
	Zinc carbonate	48.0	Good bioavailability
	Zinc oxide	72–73	Excellent bioavailability
	Zinc sulfate	22.7–36.4	Excellent bioavailability
Iodine	Calcium iodate	62.0–65.1	Excellent bioavailability
	Potassium iodide	68.7–68.9	Not as stable as other forms
	Cuprous iodide	66.6	
	Pentacalcium orthoperiodate	39.3	
	Ethylenediamine dihydriodide (EDDI)	80.1	
Selenium	Sodium selenite	45.6	Both have good availability, but both
	Sodium selenate	41.8	contain 24–27% sodium

[a] Adapted from AFMA Feed Ingredient Guide.

What are the major sources of trace minerals?

Iron, copper, manganese, zinc, iodine, and selenium are the trace minerals that should be added in a mineral premix. In Table 9, a list of the various chemical forms in which the trace minerals are available is shown. Most trace minerals are not generally supplied as pure chemicals, but as either ores or industrial by-products. Sulfate trace mineral forms are usually more reactive in the premix and possibly reduce the potency of the more susceptible vitamins and reduce the shelf life of the entire premix. However, sulfate forms often have the greatest bioavailability of any of the inorganic sources.

A suggested trace mineral premix with specified amounts and mineral sources is given in the factsheet, *Premix, Base Mix and Starter Diet Recommendations for Swine,* MF2299. This single premix can be used in diets for all ages of swine by adjusting the inclusion rate for sow, starter, and growing–finishing diets.

Vitamins

Why are vitamins necessary?

Vitamins are required for normal metabolic function; development of normal tissues; and health, growth and maintenance. Some vitamins can be produced within the pig's body in sufficient quantities to meet its needs. Others are present in adequate amounts in feed ingredients commonly used in swine diets. However, several vitamins need to be added to swine diets to obtain optimal performance. Vitamin needs are more critical today than in previous years because of the use of simple diets containing fewer ingredients and confinement facilities.

What vitamins should be added?

Vitamins that should be added to swine diets can be divided into two groups—fat-soluble and water-soluble. The fat-soluble vitamins that are generally added are A, D, E and K. The water-soluble or B-complex vitamins which may be deficient in a corn- or milo-based diet are: pantothenic acid, riboflavin, niacin and vitamin B12. The recommended levels of addition are shown in the following chapters. In addition, research has shown that additions of folic acid, pyridoxine, choline, and biotin may improve sow and litter performance when added to gestation and lactation diets. There is no need to supplement corn- or milo-soybean meat based diets for growing–finishing swine with biotin, folic acid, pyridoxine, or choline.

What about natural sources of vitamins?

Green leafy plants, grasses, and alfalfa are excellent sources of vitamins for swine. However, with increased confinement rearing and continual usage of pastures and outside lots, very often little plant material is available. In addition, with fewer ingredients used in diet formulation, there is no longer the variety of feed ingredients to supply added vitamins. Finally, vitamin content of grains and protein sources may be unavailable or lost during storage. Therefore, when formulating swine diets, we recommend specifying all vitamin and trace mineral levels as "added" levels. This helps to eliminate some of the confusion and difficulty in determining availability and concentrations in feed ingredients.

Synthetic vitamins

Because the natural sources of the vitamins may not be present in swine diets, it is recommended that a vitamin supplement be added. Synthetic vitamins are produced by many companies and are sold individually or in various combinations. Synthetic vitamins may be more accessible than some of the natural sources of vitamins.

A suggested vitamin premix is listed in the factsheet, *Premix, Base Mix and Starter Diet Recommendations for Swine,* MF2299. This premix is designed to be fed to all ages of pigs by adjusting its inclusion rate. Therefore, it is necessary to use a sow add pack for gestation and lactation diets. Although this single premix is over-fortified on certain vitamins for pigs, depending on age, there is less potential for vitamin potency losses during long storage.

Base mix recommendations

Because feed processing systems differ from farm to farm, several base mix recommendations have been included in the factsheet, *Premix, Base Mix and Starter Diet Recommendations for Swine,* MF2299, for producers who do not choose or do not have the milling capabilities to handle the small inclusion rates associated with a premix program. These base mixes contain approximately the same calcium, phosphorus, vitamin, and trace mineral levels as diets formulated with premixes. Furthermore, these base mixes can be substituted for the individual ingredients (monocalcium phosphate, limestone, salt, vitamin and trace mineral premixes) in the suggested diet formulations and provide similar nutrient content.

Vitamin stability

Even though the vitamin premix was correctly formulated before leaving the manufacturer, it does not necessarily mean that it will have adequate levels of vitamins to meet the pig's daily dietary requirements. Premix abuse can contribute to borderline vitamin deficiencies. In Table 10, factors that affect vitamin stability are shown. Some vitamins are much less stable than others; therefore, care of the vitamin premix is extremely critical for optimum performance. Vitamins, classified by their stability are listed in Table 11. In addition, because choline, trace minerals, and

Table 10. Factors that Affect Vitamin Stability[a].

Vitamins	Factor
Fat-soluble vitamins	
Vitamin A	Heat, oxidation, and moisture
Vitamin D	Heat
Vitamin E	Heat and moisture
Vitamin K	Minerals
Water-soluble vitamins	
Riboflavin	Natural and ultraviolet light
Niacin	Moisture
Pantothenic acid	pH and presence of electrolytes
Vitamin B_{12}	Oxidation, minerals, and vitamin C
Choline	Moisture
Folic acid	Temperature and moisture
Pyridoxine	Light and heat
Thiamin	Sulfate mineral forms, pH, and temperature
Vitamin C	Oxidation

[a] Adapted from Diamond–Shamrock Feed Supplement Products Manual.

Table 11. Vitamin Stability in Premixes, Pelleting and Extrusion[a].

	Stability				
	Very high	High	Moderate	Low	Very low
Vitamin	Choline Chloride	Riboflavin	Thiamine	Thiamine HCl	Menadione
	B_{12}	Niacin	Folic Acid	Ascorbic acid	
		Pantothenic acid	Pyridoxine		
		E	D_3		
		Biotin	A		
	Losses per month, %				
Premixes without choline and trace minerals	0	<0.5%	0.5%	1%	2%
Premixes with choline	<0.5%	0.5%	2%	4%	6%
Premixes with choline and trace minerals	<0.5%	1%	8%	15%	30%
Pelleting	1%	2%	6%	10%	25%
Extrusion	1%	5%	11%	17%	50%

[a] Source: BASF Technical Bulletin.

different processing methods can increase the potential for vitamin oxidation, monthly vitamin losses are also listed in Table 11. To maintain vitamin potency, it is highly recommended that vitamins be stored in a dry, cool, dark place. Because vitamins are hygroscopic (absorb moisture) vapor barriers such as plastic-lined sacks will aid in reducing moisture levels, especially when the humidity is high. If choline and trace minerals are present in combination with the vitamins in the premix or base mix, storage time should not exceed 60 days.

Should choline be supplemented in swine diets?

Choline is important in nerve function, protein synthesis, and structural development. Choline in the strict sense is not a vitamin, because pigs can synthesize sufficient choline for their needs, provided that specific chemical substances are available. Choline is one of the most expensive vitamins added to premixes. It may represent 10 to 25 percent of the cost of vitamin supplementation. The cost of choline in gestation diets can be justified by the increase in the number of live pigs born and weaned when it is added at the rate of 500 grams per ton of complete feed.

In the past, the cause of spraddle legs in baby pigs has been attributed to a deficiency of choline. Research indicates that choline deficiency is not a major factor in this condition. The cause(s) of spraddle legs is not fully understood, but it may involve several factors including: genetics, management, slick flooring, mycotoxins, and a virus or combination of viruses.

Although the requirement for choline has not been defined, 150 grams per ton of complete feed is recommended as a safety factor for pigs less than 15 pounds, but not for growing–finishing pigs.

How much vitamin E should be added to swine diets?

There is much debate as to how much vitamin E should be added to swine diets. This is a result of the many factors that influence vitamin E concentrations and requirements. Some of these include: artificial drying of grains, storage time and conditions, unsaturated fatty acids, and selenium concentrations. Because of the high incidence of Mulberry Heart Syndrome in Kansas swine herds, we recommend that 40,000 IU/ton of vitamin E be added to sow and baby pig diets.

Why is vitamin K (menadione) added?

Although vitamin K occurs in many natural feedstuffs and is also synthesized by intestinal microflora of the pig, a deficiency can be caused by low stability and moldy feeds. Deficiency characteristics are hemorrhaging and prolonged blood clotting time, but can also include blood-tinged urine, lameness and listlessness. When specifying vitamin K requirements, it is important to indicate menadione, which is the active form of the vitamin.

Is it necessary to add vitamin C to swine diets?

Several experiments have been conducted to determine the value of supplemental vitamin C or ascorbic acid in swine diets. The majority of the research indicates that vitamin C supplementation will not improve pig performance. However, some research has suggested that added vitamin C increased sperm production in heat stressed boars.

What is carnitine, and do I need to add it to my swine diets?

Carnitine is a vitamin-like compound primarily responsible for transporting fatty acids across the mitochondrial membrane. Recent research has observed finishing pigs fed added carnitine to have reduced backfat thickness. Carnitine may also increase birth and weaning weights when fed to sows. However, like chromium, careful evaluation of the cost and potential benefits (possibly involving on-farm evaluation) need to be considered.

Is it necessary to add pyridoxine to swine diets?

Pyridoxine (vitamin B_6) was generally thought to be adequate in a grain-soybean meal-based diet to meet the pig's requirement. However, recent research has observed an improvement in growth performance of weanling pigs fed 3 g/ton of added pyridoxine. However, this improvement was only observed the first two weeks after weaning. Therefore, because it appears for now that older pigs may not need added pyridoxine, we suggest adding 3 g/ton in SEW and Transition diets.

Is it necessary to add biotin, pyridoxine, and folic acid to sow diets?

Biotin, pyridoxine, and folic acid are water-soluble vitamins that have been studied to evaluate their influence on overall reproductive performance. Biotin deficiency has been associated with foot lesions and toe cracks in sows. However, research is contradictory, with some experiments finding benefit from biotin additions and others not. The availability of biotin in grain may be a possible factor for these discrepancies. Therefore, 200 mg/ton biotin is recommended to be added to sow gestation and lactation diets as an insurance factor.

Pyridoxine has typically not been recommended for use in sow diets because the amounts in grain and soybean meal were thought to be adequate to meet the sow's requirement. However, research from Canada recently demonstrated increased number of pigs born to sows fed added pyridoxine. Therefore, 13,750 mg/ton pyridoxine is recommended to be added to sow gestation and lactation diets.

Folic acid participates in many enzymatic reactions that appear to be essential in assuring embryo survival. Research has indicated that the addition of 1,500 mg/ton of complete feed will increase the number of pigs born alive by approximately 1 pig per litter.

What management changes have affected vitamin and mineral nutrition?

In the last 10 to 15 years, vitamin and trace mineral additions have become increasingly important because of changes in feeding, housing and management systems. Some of the more important changes include:

1. Increased confinement production has denied swine access to soils and grazing crops, which provided vitamins and minerals.
2. Increased use of slotted floors has prevented recycling of feces, which may be high in B-vitamins and vitamin K that are synthesized by microorganisms in the large intestine.
3. Reduced use of multiple protein sources in diets. If multiple protein sources are used, they often complement each other in providing the vitamin and mineral needs of swine.
4. Reduced daily feed intake during gestation. Dietary vitamin and mineral concentrations must be increased as daily feed intake is decreased. With the trend towards moving sows from outside gestation lots into environmentally controlled buildings, maintenance requirements and feeding levels will be lowered. Therefore, to prevent shortages with decreased feed intake, vitamin and mineral requirements should be expressed on an amount/day basis rather than percentages.
5. Earlier weaning of pigs. There is increasing pressure to wean pigs at an earlier age. Two- and 3-week weaning is commonplace. As weaning age decreases, the quality of the diet with respect to all nutrients becomes more critical.
6. Bioavailability of nutrients in heat-dried grains and feed ingredients appears to vary widely. Inhibitors and molds in feed may result in reduced absorption, thereby increasing requirements for certain vitamins.

Should I eliminate vitamin and trace mineral premixes from late finishing pig diets?

As the pig approaches market weight, the need for high levels of vitamins and minerals for maximum growth rate appear to decrease. In fact, recent research suggests that for the last 40 to 50 pounds of gain, added vitamin and trace mineral premix may not be necessary for maximum lean growth and carcass characteristics. Therefore, some producers may attempt to take advantage of the $.25 to .30 per pig savings by removing the vitamin and trace mineral premixes in late finishing (last 40 to 50 pounds of gain). However, producers should be made aware of the potential disadvantages of this management practice.

1. Removal of vitamin and trace mineral premixes is not recommended for replacement gilts destined to enter the breeding herd.
2. Feeders must be emptied in between groups of pigs so that leftover feed will not be fed the next group of pigs. Starting growing pigs on a diet without vitamin and trace minerals even for a short time could negate any potential savings later in the finishing stage.
3. Barns need to be run strictly on an all-in-all-out basis. Pigs not marketed and transferred into the next marketing group could end up being fed the late finisher diets for an extended period resulting in deficiencies.
4. Field reports have indicated an increase in the incidence of fractured bones in pigs fed very low Ca and P or diets without added Ca and P during processing. These fractures lead to increased trim loss that will offset the potential savings. Therefore, the reduction in minerals should not be too severe, nor the length of feeding more than the recommended last 40 to 50 pounds of gain.
5. Although current research data suggests no detrimental impact of removing the vitamin and trace mineral premixes on pork quality traits, such as color or shelf-life, more indepth research on the effects on pork's nutritional value and its impact on consumer attitudes towards pork need to be determined.

Water

Why is water important?

Water is so common we seldom think of it as a nutrient, but it is probably the most essential and the cheapest of all nutrients. Depriving pigs of water reduces feed consumption, limits growth and feed efficiency, and causes lactating sows to produce less milk. Water affects many physiological functions necessary for maximum animal performance. Among these are temperature regulation, transport of nutrients and wastes, metabolic processes, lubrication and milk production.

How much water do pigs need?

The water requirements of swine are variable and governed by many factors. Water accounts for as much as 80 percent of body weight at birth and declines to approximately 50 percent in a finished market animal. The need for water is increased when a pig has diarrhea. High salt intake, high ambient temperature, fever, and lactation also markedly increase water requirement.

Water requirement has a relationship to feed intake and to body weight. Under normal conditions, swine will consume 2 to 5 quarts of water per pound of dry feed or 7 to 20 quarts of water per 100 pounds of body weight daily. A rule of thumb is that self-fed hogs will consume one and a half to two times as much water as feed.

Temperature will affect water intake. Additional energy is required to warm liquids consumed at temperatures below that of the body. Lactating sows must have unlimited access to water (about 5 gallons a day) if they are to milk adequately, and suckling pigs past 3 weeks of age need water in addition to that in sows' milk for optimum performance. Free access to water located near feeders is desirable.

Will water flow rate affect performance?

Recent research has shown that water flow rate will have little effect on growing-finishing pig performance. However, pigs will take longer to drink when water flow rate is reduced. Suggested water flow rates based on phase of production are listed below:

Recommended Water Flows

Nursing pigs and hot nursery pigs:
- 1 cup (250 cc) of water per minute.

Pigs from 25 to 50 lb (nursery):
- 2 cups (500 cc) of water per minute (1 pint).

Pigs from 50 to 125 lb (grower):
- 3 cups (750 cc) of water per minute.

Finishing hogs, 125 lb to market:
- 4 cups (1000 cc) of water per minute (1 quart).

Sows (gestation and lactation) and boars:
- 4 cups (1,000 cc) of water per minute (1 quart).

Is wet feeding beneficial to pig performance?

There has been renewed interest in wet feeding, and several "wet" feeders are available on the market. Research with starter pigs has indicated that wet feeding results in poorer feed efficiency. However, research with finishing pigs has shown a slight improvement in feed conversion and approximately 50 percent less water wastage; thus, reducing manure storage requirements. Probably the biggest concern with wet feeding is the increase potential for spoilage and mold problems from wastage. Therefore, if using wet feeders, feeder management and cleaning will be increased.

Will high levels of minerals in the water source affect performance?

Saline waters are found occasionally throughout the United States and cause concern about their use as drinking water for man and livestock. Minerals most commonly found in ground and surface waters are sulfates, chlorides, bicarbonates, and nitrates, which form salts with calcium, magnesium, or sodium. The combined concentrations of these minerals are called total dissolved solids. Heavy applications of fertilizers to fields, contamination of run-off water by animal wastes, and severe drought can increase the potential for water quality problems.

Sulfates. Sulfate salts are of special concern because of their laxative effects. Some effects of high levels of sulfates in drinking water for swine are: (1) diarrhea, (2) poor gains and feed efficiency, (3) nervousness, (4) stiffness of joints, (5) increased water consumption, and (6) decreased food intake. Researchers have reported an increase in scouring of growing pigs consuming water containing 3,000 parts per million sulfates, but gain and feed efficiency were not affected. This level of sulfates did not adversely affect reproductive performance of sows.

Nitrates/Nitrites. Nitrites impare the oxygen carrying capacity of the blood by reducing hemoglobin to methemoglobin. The conversion of nitrate to nitrite in water is necessary for toxicity to occur. Research has indicated that approximately 100 ppm nitrate nitrogen is generally safe. However, 300 ppm nitrate nitrogen can result in toxicity.

Total Dissolved Solids. It appears that for swine, moderate contamination of water supplies by sulfates or nitrates may be intensified by concentrations of other dissolved minerals. Total dissolved solids measures minerals that contribute to the salinity of the water, such as sodium chloride, and calcium and magnesium salts. High TDS may lower the toxicity levels for sulfates and nitrates. Approximately 5,000 parts per million appears to be the maximum safe level of total dissolved solids in drinking water for swine without adverse affect on performance.

Feed Processing

Grinding is the most common method of feed processing for the swine producer and nearly all feed ingredients will be subjected to some type of particle size reduction. Particle size reduction increases the surface area of the grain, allowing for greater interaction with digestive enzymes, thereby improving feed efficiency. Grinding also improves the ease of handling and mixing characteristics. However, fine grinding will increase the energy costs of feed processing and may result in the feed bridging in feeders and bulk bins, increased dustiness, and the potential for gastric ulcers. Therefore, the increased costs of fine processing must be offset by the resulting improved feed conversion. For more details on specific areas of feed manufacturing, the Feed Quality Assurance Handbook offered through the Department of Grain Science and Industry is a recommended reference and the NPPC Feed Purchasing Manual.

Feed processing systems

There are basically four systems of preparing diets for a swine operation. The goal for a nutrition program should be to provide each pig at the feeder with quality feed at a cost-effective price. This is not the same as least cost per ton of feed produced. Outlined below is a brief description of each system of diet preparation.

A. **Complete Feed.** Complete feeds are prepared and delivered by a commercial mill as a ready-to-feed product. Toll milling, where a local feedmill will prepare customized diets based on a producer's specifications, is quickly becoming an economical alternative to on-farm feed manufacturing in some areas.
B. **Grain and Supplement.** Mixing producer-raised grain and supplement has been popular for a long time. In most cases, a basic 40 percent protein supplement is added to grain to provide the proper nutrients. This system may be more expensive than the base mix system.
C. **Base Mix Program.** Base mixes contain all needed ingredients except grain and protein and usually account for 2.5 to 5 percent of the diet by weight. Base mixes are a cost-effective way to make swine diets on the farm and fit well with many portable feed systems. Base mixes also work well with volumetric and stationary mills. The terminology "premix" is often used erroneously by some feed companies to describe their base mix products.
D. **Premix Program.** Premixes offer the greatest opportunity for specifically tailored diets at a lower cost. Accuracy in preparation and ingredient care are critical in good premix diet formulation. When equipment and personnel allow, a premix program is suggested as the most precisely designed and cost-effective diet preparation system. Premixes of vitamins and trace minerals are added with macro minerals (dicalcium phosphate, limestone, and salt) to a protein and grain mixture.

As a producer assumes more responsibility for mixing their own feed, diet costs may be decreased. However, often the producer is unaware of the increased demands associated with on-farm feed preparation. The producer must supply additional facilities, labor, and quality control over a wide range of feed ingredients as well as provide the purchasing functions for all inputs into the program. This includes nutrient variability, vitamin and mineral stability, as well as adequate storage, processing, and mixing of diets. Therefore, before considering changing from one level of diet formulation to the next, the producer must be aware of the advantages and disadvantages of on-farm feed preparation.

In addition to increasing responsibility for quality control, management, labor, and diet formulation, there will be increased capital investment (i.e. storage bins, mixing and weighing equipment, tractors, etc.) with on-farm mixing. Very often, these costs are underestimated, and it is important to emphasize that these services are provided when complete feed is purchased.

However, as you move from complete feed to a premix program, you increase diet flexibility. Diets can be specifically formulated to fit your operation, facilities, genetics and environment. Probably the biggest advantage with taking more responsibility in mixing your own feed is a possible reduction in feed cost. This is accomplished by not paying someone else to ensure quality diet formulation. The National Pork Producers Council's Feed Purchasing Manual provides additional information on the pros and cons of feed or ingredient purchasing.

What is the optimum particle size?

There has been a lot of confusion concerning the optimum particle size of swine diets. This has been a result of broad classifications like "fine, medium and coarse," used to define particle size. In addition, different grains, because of their kernel size, hardness, shape, and moisture content will produce a different particle size when ground through the same screen. The rate at which grain enters the hammermill or roller mill can also influence particle size. At present, considering improvements in feed efficiency, processing costs, incidence of gastric ulcers, and potential for bridging, we recommend an average diet particle size of 700 microns. In addition, fine (600 to 700 microns) grinding of high-fiber feed ingredients has been shown to improve their feeding value. As a rule of thumb, if there are whole kernels in your feed, it is probably not ground fine enough, and you may be losing 5 to 8 percent in feed efficiency. Results of over 6,500 samples analyzed at K-State since 1985 indicate that 70 percent of the samples are over 800 microns in particle size.

Should I process my feed with a hammermill or a roller mill?

This is one of the most frequently asked questions concerning particle size reduction. Either mill, if properly designed, is capable of producing the desired particle size. However, there are advantages and disadvantages that must be considered to determine the best mill for your operation. Hammermills can change from grinding one grain to another by changing screens. However, a hammermill requires more energy than a roller mill and will produce a higher percentage of fines and dust. A roller mill requires about 28 percent less energy to produce a 700 micron particle size than a hammermill, but if grain types are to be changed frequently, the roller mill will need to be adjusted for each grain. For processing grain with a hammermill, screen size will vary based on type of grain. Corn and wheat may be processed through a hammermill equipped with a 5/32- or 3/16-inch screen, whereas a 1/8-inch screen is recommended for processing milo, barley, and oats. By using these screens with the respective grain, approximately a 700 micron diet particle size should be achieved.

Condition of screens and rollers will be critical in grinding efficiency and maintaining optimum particle size. Screens and hammers need to be checked at least monthly for wear and replaced if screen damage occurs or if the holes become funnel shaped. Hammers can also be reversed or replaced if they become worn. In roller mills, three criteria are essential in producing a 700 micron particle size: (1) the rolls should be moving with a differential drive of one roll moving 50 to 75 percent faster than the other to produce a shearing action that will help "cut" the kernel rather than crush it; (2) The rolls should have corrugations to help slice the grain, with the desired corrugations per inch of roll being 8 to 10 for corn, 10 to 12 for wheat, barley, and oats, and 12 to 14 for milo; (3) the corrugations should have a 1- to 2-inch spiral to increase the shearing potential and eliminate fines. In addition, it is generally easier to produce feed with a 700 micron particle size with a double high roller mill compared with a single pair roller mill. Magnets and scalpers are very important to remove any metal objects from the grain and increase the longevity of hammers, screens and rollers. Both hammermills and roller mills should be checked periodically for wear.

How beneficial are other processing methods?

There are many different methods for processing feed for pigs. In addition to grinding, the most common forms of feed processing are pelleting, expanding, extruding and roasting. Pellets can be made of different lengths, diameter, and degree of hardness. The ingredients of the diet will influence the hardness of the pellet and pellet quality. Various studies suggest a 3 to 10 percent improvement in growth rate and feed efficiency when pigs are fed pelleted diets compared to a meal. This appears to result from less feed wastage with pelleted feeds. Pelleting appears to improve the nutritional value of high-fiber feed ingredients to a greater extent than that of low-fiber ingredients. This may be a result of increasing the bulk density of the feed. As with any feed processing method, the increased processing cost must be offset by the improved feed efficiency of pigs fed the pelleted diet.

Expanding. Expanding (high-shear conditioning) converts mechanical energy into frictional energy to modify (cook) certain components of the diet. This process is typically performed prior to and in conjunction with pelleting. Current data would suggest limited improvements in growth performance of pigs fed expanded diets. However, the most consistent improvements associated with expanders are in the areas of pellet quality, pellet throughput, and improved microbiological control of the complete feed.

Extrusion and Roasting. Extrusion processing involves the application of heat, pressure, and (or) steam to an ingredient or diet. Extruders are sometimes used for on-farm processing of soybeans. If properly heated, this is an easy way to add fat to swine diets and utilize home grown soybeans. Research has shown that moist extruded soy protein concentrate or soybean meal as well as dry extruded whole soybeans are excellent protein sources for baby pigs. Because of volume, tonnage, and processing costs, extrusion of complete feeds is usually not economically justified based on performance of pigs fed extruded complete feeds. Extrusion processing increases the bulkiness of the diet, making it more difficult for the pig to consume enough feed to meet its nutrient requirements. Roasting can also be used to process home-grown soybeans. This can also be an alternative method for adding fat to swine diets. However, roasting temperature and times must be checked to ensure adequate processing. The added cost of the extruded, or roasted products must be the ultimate consideration in determining the feasibility of their use in swine diets.

Other Processing Methods. Several alternative processing methods are available to swine producers. Steam flaking, micronizing, and other processing methods often do not improve pig performance enough to justify the added expense of processing. When evaluating the expense of feed processing methods, the following equation will determine if it is justified:

$$\frac{\text{New Cost} - \text{Old Cost}}{\text{New Cost}} \times 100 < \text{\% improvement in efficiency needed to offset added diet costs}$$

Can I mix my own feed on the farm?

As outlined in the introduction of this guide, swine producers have several options for mixing feed. In general, there is a trend towards taking more of the responsibility for mixing feed. This generally lowers feed costs and increases the flexibility a producer has in mixing several different diets, but more time, labor and facilities will be required. Probably the biggest concern is that the producer must now take on the added responsibility of quality control to ensure a properly formulated and mixed diet. It is difficult to determine the size of operation for which it is profitable to assume mixing and formulation responsibilities. This will also vary with the preference and goals of the producer. A commonly suggested tonnage at which one should consider replacing purchased complete feed or supplements with soybean meal and base mixes or premixes is between 500 to 750 tons per year. To calculate the distribution of your feed costs, it is estimated that a sow and her pigs will require approximately 7.3 tons of feed per year. More specific information on calculating feed budgets are included in the factsheet, *Growing–Finishing Pig Recommendations,* MF2301.

By multiplying your present feed cost per phase by the projected tonnage, you can quickly see where the bulk of your feed dollars go. This is often a helpful analysis to determine the cost comparison between feeding programs. Comparing these values to your actual usage is also a useful diagnostic indicator to see if you are feeding the correct feed for the correct period of time, i.e., not over-feeding one phase and under-feeding another.

In addition to particle size reduction, the producer must also be concerned about whether or not the feed is being mixed properly, and ingredients must be accurately weighed. A preferred way to accomplish this is with a gravimetric scale rather than a volumetric meter. If a volumetric meter is used, it must be recalibrated often, because bushel weights change frequently. With a premixing system, only scaled, batch mixing operations, not volumetric mills, should be used.

Mixers and mixing time vary considerably. Mixing times for horizontal mixers are approximately 5 minutes. Worn ribbons or paddles will increase the time necessary to adequately mix a batch of feed. Vertical mixers and on-farm grinder–mixers generally require approximately 15 minutes to mix a batch of feed. Tests have shown that over-filling mixers greatly increases the amount of time needed for mixing. Worn ribbons and screws will also contribute to increased mixing times. Very often, manuals underestimate the amount of time necessary for feed mixing. A mixing test is a sure way of knowing the correct mixing time for your mixer. Mixing efficiency can be measured by taking several samples of feed from one batch cycle and analyzing them for salt content. The variation between samples in salt content is used as an indicator of properly mixed feed (< 10%). If feed is under-mixed, this will be more of a problem for young pigs because they eat only a little feed. Larger pigs, however, by virtue of their greater feed intake, may be less susceptible to marginally mixed feed. The sequence in which feed ingredients are added to a mixer may influence mixing efficiency and feed uniformity. Ingredients should be added in the following order: (1) half of the grain; (2) protein sources, vitamins, minerals and feed additives; (3) the remainder of the grain.

Can I over-mix feed?

There is a common misconception that feed, if mixed too long, can become “unmixed.” Tests have indicated that feed reaches a “steady state” of being mixed and remains at or near that point for an extended period of time.

How can I monitor quality control?

As you assume more responsibility for mixing your own feed, quality control will be vital to avoid use of inferior feed ingredients. A stringent and tough quality control program will help in this effort. Quality control programs will vary based on the size of the operation and tons of feed used. However, the following is a suggested program indicating the items to check and how often. These are only suggestions, and you may check them more or less frequently as you see fit.

Particle size. Based on the tonnage processed per year, particle size should be checked every 400 to 600 tons of feed processed. If you notice whole kernels or even half kernels, these can be indicators of a hole in a screen or worn hammers or rollers.

Mixing Efficiency. Mixers should be checked for proper mixing times when they are first installed, then updated periodically as screws, augers and paddles become worn. This can be once every year or two, depending on tonnage mixed.

Grains. Moisture content, protein, and test weight will be most critical as indicators for determining grain quality. In addition, foreign materials and presence of molds or other contaminants that can occur because of improper storage should be noted. A moisture tester and a blacklight (for aflotoxins) can be a practical means for on-farm testing of grain quality. It is recommended to check protein content, test weight, moisture, broken kernels, and foreign material twice per year for home raised grains and with every purchase of off-farm grain until consistent quality is assured. If suspect, grain should also be analyzed for molds and mycotoxins.

Soybean meal. Soybean meal is the most common protein supplement used. Standards are established for protein, fiber and moisture. The purchaser is entitled to price adjustments should these criteria not meet set standards. However, this price adjustment does not happen automatically. The producer must have the soybean meal analyzed and request a price adjustment. When purchasing a new load, request an official sample and ask the company for a written description of the content. Then send the sample to a refereed analytical laboratory for analysis. You may decide to take a duplicate sample for analysis when it is unloaded. Every load should be tested for protein and dry matter content. In addition, calcium and phosphorus should be tested periodically and whenever changing suppliers. Generally, 46.5 percent soybean meal will have less fiber and be a more consistent protein source than 44 percent soybean meal. Other protein sources are often variable in nutrient content and should be analyzed for protein content as an indicator of amino acid content. This variation is often a hidden cost of using alternative protein sources.

Dried whey, fish meal, and spray-dried blood coproducts. Because these ingredients are often added to baby pig diets, quality is essential. We recommend specifying “edible grade” dried whey, “select menhaden” fish meal, and “spray-dried” blood products. These products often have excellent and predictable nutrient quality. Research has indicated that spray-dried blood meal greatly improves growth performance of early weaned pigs compared with those fed flash- or ring-dried blood meal.

Dicalcium phosphate or monocalcium phosphate and limestone. A common problem for producers is formulating their diet with dicalcium phosphate (21 percent Ca and 18 percent P) and buying monocalcium phosphate (18 percent Ca and 21 percent P). Always check feed tags and ingredient labels.

Complete supplements, base mixes, and vitamin and trace mineral premixes. These should be checked periodically for certain nutrient content. Generally, this will include screening for two to four nutrients and rotating the nutrients checked with each batch. Base mixes and premixes should be checked with every change of supplier and then periodically, (every two to four months). Base mixes should be tested for calcium, phosphorus, a vitamin (alternate), and trace mineral (alternate). In addition, once per year a complete mineral analysis (Ca, P, Fe, Zn, Mn, Cu, and NaCl) is recommended. Premixes should also be checked with every change of supplier and then periodically. One fat soluble (alternate) and one water soluble (alternate) vitamin should be checked for vitamin premixes and one trace mineral (alternate) should be checked in trace mineral premixes. We recommend checking the more expensive nutrients, such as protein, phosphorous, vitamin E, and riboflavin.

Fats and oils. Rancidity may be the biggest problem with fat and oil sources. If questionable, check for free fatty acids, MIU, (moisture, impurities, and unsaponafiable material) and initial peroxide value. A high quality fat source is essential in formulating swine diets. When storing fats or oils for long periods of time, it is suggested that they be stabilized with an antioxidant, such as ethoxyquin, BHT, or BHA.

Complete diets. If a stringent quality control program is followed on all incoming ingredients and processing, there should be little need to check the final product. However, periodically checking one or two of your diets on a rotational basis is a good way to double check your system. Check for moisture, protein, and possibly calcium and phosphorus.

The preceding items have been suggested to monitor because they are typically the more expensive nutrients and are most likely not to exceed minimum requirements.

What steps should I follow to ensure diet quality?

1. Fill out a diet formulation sheet, including prices and as much diet content information as possible. Feed tags and a complete ingredient description should be included when possible. These records can provide important historical information about your operation's feeding program.
2. Check your calculated nutrient composition and compare it to those suggested by Kansas State University.
3. Check your diets frequently. Again, check the tonnage used by each phase of production to make sure you are not over-feeding or under-feeding a diet. Also, continually check prices of your diets and cost per cwt. of pork sold.

How do I take a good sample?

Nutrient composition can vary within each specific batch of feed to such a degree that chemical composition can be significantly altered based on a non-representative sample. Thus, a composite sample that is representative of the complete batch mix is the key to successfully determining nutrient concentrations. Sampling is a step-wise procedure that must be scrutinized heavily to ensure that proper samples are obtained. First, identify the most practical method of sampling based on the mixing system, feeding program, and the purpose of the sample. Samples taken to determine mixing efficiency are not composite and must be analyzed individually, whereas samples taken to determine crude protein, calcium, amino acids, etc., must be composite to determine average composition. Thus, the first step is identification of sampling location. The following locations are acceptable for obtaining samples.

Mixer. Samples can be taken using a grain trier/probe from separate locations within the mixer; approximately 10, 1-pound samples should be taken and combined into one composite sample for chemical analysis or kept separate for mixing efficiency tests. The most common method of sampling a mixer is to obtain 10 samples at the discharge outlet while unloading the mixer. Care must be taken to avoid sampling the initial output as well as the final output, because these can be extremely variable.

Bulk feed. Samples should be taken during the loading or unloading process, and at timed intervals to ensure that a representative sampling is obtained. Samples are best obtained using an in-line, automatic sampler while moving the product to a bin or while loading a truck or car. However, grab samples may be obtained while unloading the product at the destination. The samples can be combined for chemical analysis or kept separate for mixing efficiency tests.

Sacked feed. Samples should be obtained using a bag trier/probe. Samples taken by hand, with a cup or with a dipper, are most common, but often fail to provide the best possible sample. Ten, ½-pound samples should be obtained, but deviation may be necessary depending upon the number of sacks in the lot. The bag should be laid horizontally and probed diagonally from end to end. From lots of 1 to 10 bags, sample all bags; and from lots greater than 11 bags, sample 10 bags. Samples should be combined for chemical analysis and are probably not best used for mixing efficiency tests.

How do I go about bidding my feed business?

Bids for the feed business of a swine operation can be conducted on complete feeds, supplements, base mixes, or premixes. The format for setting up a bidding system is simple, with the producer working with his or her nutritionist, veterinarian, or consultant to set up guidelines for nutrient specifications. These guidelines are then submitted to interested feed manufacturers who will submit a bid for the producer to consider. It is essential that the producer follow these few steps to ensure the fairness of the bidding procedure. Additional information can be found in the NPPC Feed Purchasing Manual.

1. Write extremely clear and narrow nutrient specifications so that products cannot be misrepresented.
2. List all essential nutrients that must be included in the product to be bid on. Make sure you do not leave out any nutrients. This is a common mistake made by producers. Any additional nutrients or ingredients that a feed company includes in the product are extras with no nutritional or economic value.
3. List all nutrient levels per pound or ton that must be guaranteed in the product. These guaranteed levels (maximums or minimums) will be used in the quality control program. A common mistake is that producers will specify 500 grams of choline chloride when they want 500 grams of choline. In a bidding process, 500 grams of choline chloride (50 percent choline) would leave the final diet 50 percent short on meeting the pigs' choline requirement.

4. List the desired ingredient sources for each of the nutrients. This is essential to provide uniform product comparisons.
5. Include any desired mixing directions, nutrient carriers, or information that will help the feed company meet the customer's needs. This may also include medications and the desired levels.
6. Specify how much of a product is to be provided and (or) the length of the agreement. Also include items, such as where materials are to be delivered or picked up.
7. A quality control program must be specified including a sampling procedure and analysis program. In case specifications are not met, possible reimbursement schedules for the termination of contracts should be defined.

What is an open formula?

An open formula is a listing of ingredients and nutrient concentrations supplied in a complete feed, protein supplement, base mix, or premix. This information is listed on the feed tag and readily available to the producer. It can be used to compare prices based on nutrient specifications to ensure that they meet the pig's requirements. Closed formulas do not provide nutrient specifications, thus making it virtually impossible to determine cost/unit nutrient or the nutrient levels provided in the diet.

In order to make sound economic and management decisions concerning feeds and feed ingredients, we strongly encourage the use of open formulas in swine diet formulation.

Will having feed chemically analyzed aid in diet formulation?

Yes, because individual feed ingredients will vary for the reasons explained above, testing results will aid in diet formulation. An alphabetical list of commercial analytical laboratories is shown in Table 12. This listing is for information only and does not constitute an endorsement of the labs listed nor a discredit to any lab inadvertently omitted from the list. It is suggested that you contact the lab of your choice for a price list and for instructions on size of sample, sample methods, and mailing.

What kind of variation can I expect in lab analyses?

It is extremely important to understand that if a specific nutrient guarantee is not confirmed by an analytical procedure, that this is not entirely a result of an inferior product. Two of the largest and most important sources of possible error are representative sampling and analytical variation. To try to minimize possible error in analytical testing, a representative sample must be collected, subsampled and stored. Therefore, the steps and procedures for sampling outlined earlier in this section should be followed. In addition, the Association of American Feed Control Officials (AAFCO) establishes definitions of feed ingredients as well as minimum and maximum nutrient levels for specific nutrients and ingredients. They also establish guidelines for variation of analysis of nutrient content within feeds or ingredients (Table 13). These can be used as a reference point for determining acceptability of ingredients or finished products based on analytical testing. They are not intended to allow real deficiencies or excesses of the guaranteed ingredient, nor are they intended to cover sloppy work, poor sampling, or any deficiency in analytical or clerical procedures. The acceptable variation is established by AAFCO by sending the same sample to several different labs to determine the variation between results from each lab. There are several key nutrients that do not have established permitted analytical variation allowances (such as amino acids). For these nutrients, the supplier and customer should mutually determine the acceptable allowances. Analytical variation allowances for feed medications can be found in the AAFCO (1994) Official publication. Analytical variation is not reported for amino acid analysis, but variation from 20 to 30 percent can be anticipated.

Composition of ingredients

In formulating diets to meet recommended nutrient requirements of swine, it is necessary to know the nutrient composition of each ingredient used. Composition of ingredients commonly used in swine diets are given in Table 14.

Individual ingredients can vary widely in composition because of the variation in species or variety, storage conditions, climate, soil moisture, and agronomic differences. Variations in chemical analytical procedure also affect values obtained. Therefore, the values given are an average and are subject to variation.

Table 12. Commercial Analytical Laboratories for Feed Analyses[a].

Company	Address	Phone
Altecha LTD (Water Analysis only)	731 McCall Road Manhattan, KS 66502	785-537-9773
Colorado Analytical Laboratory	P. O. Box Drawer 507 Brighton, CO 80601	303-659-2313
Doty Labs	1435 Clay Street North Kansas City, MO 64116	816-471-8580
Farmland Industries, Inc. Analytical Services	3705 North 139 St Kansas City, KS 66109	913-721-1653
Iowa Testing Lab	Highway 17 North P.O. Box 188 Eagle Grove, IA 50533	515-448-4741
Livestock Nutrition Laboratory Services	P.O. Box 1655 Columbia, MO 65205	314-445-4476
Midwest Laboratories, Inc.	13611 B Street, Omaha, NE 68144-3693	402-334-7770
Peterson Lab	19 East 4th Street Box 886 Hutchinson, KS 67504-0886	316-665-5661
Scott-Pro Inc.	P. O. Box 587 Scott City, KS 67871	316-872-2189
Servi-Tech, Inc.	Box 1415 Dodge City KS 67801	316-227-7123
Servi-Tech, Inc.	P.O. Box 169 Hastings, NE 68901	402-463-3522
Veterinary Diagnostic Laboratory (Mycotoxins only)	NDSU Box 5406 Fargo, ND 58105	701-231-8307
Woodson–Tenant Lab	3507 Delaware Avenue Des Moines, IA 50313	515-265-1461

Table 13. Permitted Analytical Variations (AV) Based on AAFCO Check Sample Programs.

Analysis	Determination method	AV%[b,c]	Concentration range
Moisture	934.01, 930.15, 935.29	12	3–40%
Protein	954.01, 976.05, 976.06, 984.13	(20/x + 2)	10–85%
Fat	920.39, 954.02, 932.02	10	3–20%
Fiber	962.09, 972.10	(30/x + 6)	2–30%
Ash	942.05	(45/x + 3)	2–88%
Pepsin digest, protein	971.09	13	
Total sugar as invert	925.05	12	24–37%
NPN protein	941.04, 967.07	(80/x + 3)	7–60%
Calcium	927.02	(14/x + 6)	.5–25%
	968.02	10	10–25%
		12	< 10%
Phosphorus	946.06, 965.17, Auto Anal.	(3/x + 8)	.5 –20%
Salt	969.10	(7/x + 5)	.5–14%
Fluorine	975.08	40	ppm
Cobalt	968.08	40	ppm
Iodine	934.02, 935.14, 925.56	40	ppm
Copper	968.08	25	.03–1%
		30	< .03%
Magnesium	968.08	20	.01–15%
Iron	968.08	25	.01–5%
Manganese	968.08	30	.01–17%
Potassium	975.03, 925.01	15	.04–8%
Zinc	968.08	20	.002–6%
Selenium	969.06	25	ppm
Sodium	a.a.	20	.2 - 4%
	ICP	15	.2 - 4%
Vitamin A	974.29	30	1200–218,000 IU/lb
Vitamin B_{12}	952.2	45	
Riboflavin	970.65, 940.33	30	1–1500 mg/lb
Niacin	961.14, 944.13	25	3–500 mg/lb
Pantothenic acid	945.74	25	4–190 mg/lb

[a] Method Reference from 15th Edition, AOAC Official Methods of Analysis.

[b] x = % Guarantee (example: for a 10% Protein Guarantee AV% = (20/10 + 2) = 4% of Guarantee. This means the low AV is 4% of 10 or .4.

[c] Analytical Variances as derived from the AAFCO Check Sample Program. The ± signs have been removed from the AV table. The table denotes a true analytical variation and not a tolerance. They apply both above and below the guarantee and are equally correct.

Table 14. Feedstuff Composition Table (As-Fed Basis)[a,b].

Feedstuffs	M.E.[c] Kcal/lb	Protein %	Crude fat %	Crude fiber %	Ca %	Phos. %	Avail phos. %	Lysine %	Threo-nine %	Trypto-phan %	Methio-nine %	Met & cystine %
Alfalfa hay, sundried	800	14	2.5	29	1.2	0.20	0.20	0.55	0.50	0.25	0.27	0.5
Alfalfa meal, dehy	775	17	2.8	24	1.4	0.23	0.23	0.85	0.71	0.34	0.27	0.56
Animal Plasma	1766	78.0	2.0	0	.15	1.7	1.7	6.5	4.8	1.4	.70	3.5
Bakery Waste, dehydrated	1695	9.8	11.7	1.2	0.1	0.24	NA[d]	0.31	0.49	0.10	0.17	0.34
Barley	1380	11.5	1.7	5	0.1	0.34	0.10	0.40	0.36	0.15	0.16	0.37
Beet pulp	1225	8.8	0.5	18.2	0.6	0.09	NA	0.60	0.40	0.10	0.01	0.02
Blood meal, spray-dried	1060	86	1.2	1	0.4	0.30	0.28	7.44	3.63	1.05	1.05	2.08
Canola meal	1225	38	3.8	11.1	0.7	1.17	0.19	2.27	1.71	0.44	0.68	1.15
Choice white grease	3515	0	100	0	0	0	0	0	0	0	0	0
Corn gluten meal	1760	42.1	2.3	3.8	0.1	0.40	0.06	0.78	1.42	0.21	1.07	1.73
Corn high lysine	1575	8.9	NA	2.5	0	0.24	0.03	0.38	0.41	0.14	NA	NA
Corn, yellow	1550	8.5	3.6	2.3	0	0.28	0.04	0.25	0.36	0.09	0.18	0.4
Corn oil	3335	0	100	0	0	0	0	0	0	0	0	0
Cottonseed meal, solvent	1160	41.7	1.8	10.8	0.2	1.17	0.01	1.70	1.23	0.48	0.49	1.06
Egg protein, spray-dried	NA	48	40	0.1	0.2	0.68	NA	3.10	2.25	0.73	1.48	2.57
Fish meal, menhaden	1500	61.2	9.6	0.9	5.2	2.88	2.68	4.74	2.51	0.65	1.75	2.33
Meat and bone meal, 50%	1035	50.9	9.7	2.4	9.4	4.58	3.02	2.89	1.60	0.28	0.68	1.14
Meat meal, 55%	1095	55.6	8.7	2.3	8.3	4.1	NA	3.09	1.78	0.38	0.73	1.41
Millet	1385	11.6	3.5	6.1	0	0.3	NA	0.26	0.40	0.17	0.29	NA
Molasses, cane	910	4.4	0.1	0	0.8	0.08	NA	NA	NA	NA	NA	NA
Oat groats	1550	15.8	6.1	2.5	0.1	0.43	0.06	0.53	0.44	0.19	0.21	0.41
Oats	1240	11.8	4.7	10.7	0.1	0.34	0.07	0.40	0.38	0.15	0.18	0.37
Peanut meal, solvent	1320	49	1.3	9.9	0.3	0.61	0.07	1.45	1.37	0.48	0.44	1.17
Poultry fat	3615	0	100	0	0	0	0	0	0	0	0	0
Rice bran	1300	14	1.5	12.9	0.1	1.37	0.34	0.61	0.53	0.21	0.26	0.47
Rye	1365	12	1.5	2.2	0.1	0.32	0.15	0.41	0.35	0.11	0.17	0.36
Skim milk, dried	1620	33.3	1.1	0.2	1.3	1.02	0.93	2.54	1.57	0.43	0.90	1.35
Sorghum grain (milo)	1480	8.9	2.8	2.2	0	0.28	0.06	0.23	0.27	0.10	0.16	0.29
Soybean meal, 44%[e]	1460	44	1.1	7.3	0.3	0.65	0.20	2.85	1.78	0.60	0.62	1.32
Soybean meal, 46.5%[e]	1535	46.5	0.9	3.4	0.3	0.64	0.15	3.01	1.89	0.64	0.65	1.40
Soybean meal, 47.5%[e]	1535	47.5	0.9	3.4	0.3	0.64	0.15	3.08	1.93	0.65	0.66	1.43
Soybean meal, 48.0%[e]	1535	48.0	0.9	3.4	0.3	0.64	0.15	3.11	1.95	0.66	0.67	1.44
Soybean meal, 48.5%[e]	1535	48.5	0.9	3.4	0.3	0.64	0.15	3.14	1.97	0.66	0.68	1.45
Soybean oil	3302	0	100	0	0	0	0	0	0	0	0	0
Sunflower meal	1195	45.5	2.9	11.7	0.4	0.94	0.03	1.68	1.63	0.60	0.82	1.55

Table 14. Feedstuff Composition Table (As-Fed Basis)[a,b] (cont.).

Feedstuffs	M.E.[c] Kcal/lb	Protein %	Crude fat %	Crude fiber %	Ca %	Phos. %	Avail phos. %	Lysine %	Threo-nine %	Trypto-phan %	Methio-nine %	Met & cystine %
Tallow	3580	0	100	0	0	0	0	0	0	0	0	0
Tankage, 60%	980	60	NA	2	4.6	2.5	NA	3	2.48	0.58	NA	NA
Triticale	1385	15.8	1.5	4	0.1	0.3	0.14	0.52	0.57	0.18	0.21	0.40
Wheat bran	980	15.5	4	10	0.1	1.16	0.34	0.56	0.41	0.25	0.17	1.43
Wheat, hard winter	1475	12.6	1.6	2.6	0	0.37	0.19	0.4	0.37	0.17	0.22	0.52
Wheat gluten, spray-dried	NA	74	NA	NA	NA	NA	NA	1.3	2.73	0.61	2.50	NA
Wheat middlings	1345	16.5	4.3	7.8	0.1	0.89	0.36	0.68	0.57	0.19	0.19	0.41
Wheat, soft winter	1495	11.4	1.6	2.3	0.1	0.36	0.18	0.36	0.39	0.27	0.22	0.58
Whey, dried	1400	13.3	0.8	0.2	0.9	0.76	0.73	0.94	0.89	0.18	0.19	0.49
Yeast, brewer's dried	1300	43.8	0.9	3	0.1	1.36	0.91	3.23	2.06	0.51	0.66	1.18

[a] Adapted from NRC (1988), NPPC Feed Purchasing Manual, Nebraska and South Dakota Swine Nutrition Guide, Swine Nutrition Guide from the Prairie Swine Centre, and NCR-42 Committee on Swine Nutrition (1992).

[b] These values are intended to be used as guidelines. Exact nutrient content of an ingredient is not constant, unless the ingredient is the result of a controlled industrial process (e.g., vitamins, trace minerals, crystalline amino acids, etc.).

[c] Metabolizable energy.

[d] NA means these values are not available for the ingredient.

[e] Amino acid levels were adapted from NCR-42 Committee on Swine Nutrition (1992).

Notes

Notes

Notes

Metric System—Mass Conversion

Equivalents
1 pound (lb) = 454 grams (g)
1 mcg/lb = 2 mg/ton
1 kilogram (kg) = 2.2 lb = 1000 g
1 mg/lb = 2 g/ton
1 g = 1000 milligrams (mg)
1 mg/lb = 2.2 ppm
1 mg/kg = 1 part/million (ppm)
1 mg = 1,000 micrograms (mcg)

To Convert
mg/g to mg/lb — multiply by 454
mcg/g to mg/g — divide by 1,000
mg/lb to mcg/g — divide by 0.454
mg/lb to ppm — multiply by 2.2
g/lb to % — divide by 4.54
% to g/lb — multiply by 4.54

Conversion Table

%	ppm	g/ton	mg/lb
0.0001	1.0	0.9	0.45
0.00011	1.1	1.0	0.5
0.001	10.0	9.1	4.55
0.0011	11.0	10.0	5.0
0.01	100.0	90.8	45.4
0.011	110.0	100.0	50.0
0.1	1000.0	908.0	454.0
0.11	1100.0	1000.0	500.0

Robert D. Goodband
Extension Specialist, Swine

Mike D. Tokach
Extension Specialist, Livestock Production and Management, NE

Steve S. Dritz
Food Animal Health and Management Center

Jim L. Nelssen
Extension Specialist, Swine

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned.

This publication is one of a series of six: (Premix, Base Mix and Starter Diet Recommendations for Swine, MF2299; Starter Pig Recommendations, MF2300; Growing–Finishing Pig Recommendations, MF2301; Breeding Herd Recommendations for Swine, MF2302; Feed Additive Guidelines for Swine, MF2303).

This and other publications from Kansas State University are available on the World Wide Web at: http://www.oznet.ksu.edu

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF2298 October 1997