K·STATE
Research and Extension

General Nutrition Principles for Swine

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Kansas State University Swine Nutrition Guide 2007

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 four 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.ksuswine.org*. The purposes of these publications is to provide the recommended nutrient allowances and answer some of the more frequently asked questions concerning swine nutrition. In some instances it is advisable to seek professional 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 while providing 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:

- Energy concentration of the diet
- Breed, sex, and genetic background of pigs
- The production system's measure of profitability, i.e., margin over feed costs vs. feed cost per pound of gain, or diet cost per ton
- The production system's finishing capacity, i.e., fixed time vs unlimited time available in finishing
- Health status of the herd
- Availability and absorption of dietary nutrients in ingredients
- Presence of molds, toxins, or inhibitors in the diet
- Variability of nutrient content and availability in the feed
- Greater use of by-product ingredients
- The use of feed additives such as Paylean

Research has indicated that pigs of different breeds or genetic background may have different capacities for production, thus different nutrient requirements. Furthermore, because of the swine industry's rapid adoption of artificial insemination and marker assisted selection, the rate of genetic progress has increased to a faster rate than traditional genetic selection programs. Nutrient requirements for nursery and grow-finish pigs may change in as little as every three years based on advances in genetic improvement.

Feed quality, including processing methods, the greater use of by-product ingredients and the subsequent variation in nutrient availability 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 compounds to promote growth will also alter nutrient utilization. Finally, factors affecting feed intake such as competition for feed, 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 changes in production.

Tables 1 and 2 list typical growth rates and sow performance standards. As an industry, we need to be aware of our past performance standards as well as keep an eye on the future in order to remain competitive and profitable.

What are some of the common mistakes to avoid in a nutritional program?

In different phases of production there are some common misconceptions about diet formulation and feed management. The goal of this guide is to try to educate producers of these pitfalls to make feeding regimens simple, practical, and provide the best possible performance at a reasonable cost.

Nursery: Common mistakes in nursery diet formulation include:

- feeding complex, expensive diets too long;
- selecting ingredients that are highly digestible, but not highly palatable; and
- using whey or protein sources that are not high quality.

Grow-finish: The most common mistakes in grow-finish nutrition programs are as follows:

- inadequate understanding the production or economic response to changing dietary energy levels in a particular production system;
- failure to match the lysine levels to the dietary energy levels;
- providing more additives and micronutrients than required;
- using a coarse cereal grain particle size;
- not always having feed available in the feeders; and
- lack of aggressive feeder adjustment.

Gestation: The most common gestating sow diet formulation problems are:

- selecting gestation dietary energy level by cost per ton instead of cost per sow per day;
- over-formulation of gestation diets;
- using synthetic amino acids in gestation diets.

The most common sow feed management problem is overfeeding sows in gestation leading to excess body condition and lower feed intake in lactation.

Table 1. Pig performance standards[a,b].

	Average	Top 10%
Nursery Performance		
ADG, lb	.84	1.05
ADFI, lb	1.36	1.46
F/G	1.62	1.39
Grow-finish performance		
ADG, lb	1.64	1.92
ADFI, lb	4.85	4.91
F/G	2.96	2.56

[a] 2005 Pig Champ Database Summary and individual producer group comparisons.
[b] Values will vary based on weaning age, beginning weights and dietary energy density.

Table 2. Sow performance standards[a].

	Percentile	
	50th	90th
Farrowing rate	78.5	86.6
Avg pigs born live	10.64	11.50
Litters/female/year	2.09	2.34
Pigs weaned/litter	9.27	10.02
Adjusted 21-day litter, wt, lb	125.2	142.5
Liveborn/ female/year	23.72	26.92
Pigs weaned/mated female/year	21.78	24.60
Preweaning mortality	12.18	7.46
Average age at weaning	18.49	20.50

[a] 2005 Pig Champ Database Summary and producer records.

Lactation: The most common lactating sow diet formulation problems are:

- using expensive fat sources;
- using expensive additives without solid data;
- under-formulation of lactation diets; and
- using ingredients with variable quality.

The most common sow feed management problem is underfeeding sows in lactation.

These issues and more will be discussed in this section and the others to help solve problems encountered in production systems.

How do I value the economics of my feeding program?

Determining the economic value of a nutritional program is a challenging process that will be different for each individual production system. Three potential methods for feeding program economics are: diet cost, feed cost per unit of gain, and margin over feed cost.

Diet cost. This is the simplest of the three methods and as the name implies, it strictly looks at a comparison of one set of diets versus another. This method will have its greatest and best application when there is no expected change in pig performance.

Feed cost per unit gain. Feed cost per pound of gain is calculated by multiplying feed efficiency by the feed cost per pound. For example if feed efficiency is 3.0:1 and diet cost is $0.06 per pound, then feed cost per pound of gain is $0.18. The best application of this method to calculate the difference between two programs is when there is an expected change in feed efficiency between the two nutritional programs without a change in growth rate.

Margin over feed costs. Margin over feed costs is the most accurate of the methods to calculate under specific circumstances. The first requirement is that a production system has a fixed amount of time on the phase that is being evaluated. (For example, if a system has only 16 weeks before the room or barn needs to be emptied for the next group of pigs.) The second requirement is that the change in feeding program not only influences feed efficiency but average daily gain (ADG) as well. For example, if we compare two nutritional programs with or with out the inclusion of 5 percent added fat we would draw the following conclusions. Assuming a 10 percent improvement in feed efficiency with the added fat diets and a 5 percent increase in average daily gain, we would make the following calculations.

Assumptions – No fat diets.	Diet cost $110/ton ($0.055 per lb) F/G = 3.0:1 ADG 1.7 lb per day 112 days in finisher
Calculations	112 days × 1.7 lb per day = 190 lb gain in finishing 3.0:1 Feed efficiency × $0.55 = $.165 feed cost per lb of gain 190 lb × $0.165 = $31.35 feed cost per pig
Assumptions - Added fat diets.	Diet cost $130/ton ($0.065 per lb) F/G = 2.7:1 (10% improvement with 5% added fat) ADG 1.79 lb per day (5% improvement with 5% added fat) 112 days in finisher $45/lb market hog price
Calculations	112 days × 1.79 lb per day = 200 lb gain in finishing 2.7:1 Feed efficiency × $0.65 = $.176 feed cost per lb of gain 200 lb × $0.176 = $35.20 feed cost per pig $35.20 – 31.35 = $3.88 increase in feed cost per pig with added fat 10 lb increase with added fat diets × $0.45 = $4.50 extra revenue $4.50 – $3.88 = $0.62 margin over feed cost with added fat.

In the above example, using diet cost or feed cost per pound of gain would indicate the no added fat diets to be more economical. However if we take into account the added weight of pigs with the added fat diets, then there is a $0.62 advantage per pig considering margin over feed costs. The most important assumption with this method is that the system runs on a fixed-time basis, i.e., 112 days in this example. If the system could take the pigs to the heavier weight of 200 pounds of gain with the no fat diets, then feed cost per pig (plus a value for the yardage for keeping the pigs longer in the barn) would be the best indicator of the most economical feeding program.

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.

Using the NE system will be of greatest value when comparing energetics of low-protein, amino acid-fortified diets. For example, soybean meal has a similar DE and ME as corn, but only 84 percent than energy on a NE basis because of its high protein content. Therefore when comparing a corn-soybean meal diet vs a low-protein amino acid-fortified diet, they will have similar DE or ME contents but the low-protein amino acid-fortified diets will have a much greater NE. The difference in NE between the two diets will result in approximately 40 kcal per pound of diet, which will improve feed efficiency.

The main energy sources for swine are the cereal grains: corn, milo, wheat, barley, and their by-products. In addition, fat, which contains approximately 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. 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 average daily gain and(or) feed efficiency.

Are corn and milo (sorghum) comparable?

Both grains are excellent energy sources in swine diets. In Kansas, milo is often a cheaper source of energy and produces more economical gains. However, with more and more acres of corn being planted in the state the economic difference between the two grains is becoming smaller and frequently favors corn. Because the energy content of corn is slightly higher than milo, feed efficiency of pigs fed corn diets will be slightly better than that of pigs fed milo, but average daily gains will be similar. A general recommendation for swine diets is that milo should be 96 percent or less the value of corn to be an economical substitute. 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 (1/8- 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. Therefore you can pay approximately 107 percent the value of corn for wheat. 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 reduced.

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. Therefore, barley needs to be 90 percent the value of corn or less to be an economical substitute. Barley also contains less biotin than corn and may need extra supplementation when used. 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.

Modified Corn Varities. Improvements in genetic selection and modification have resulted in new corn varieties with enhanced nutrient profiles for use in livestock diets. These new varieties have a higher concentration of nutrients such as amino acids, energy, and lowered phytate phosphorus. Recent research has demonstrated positive utilization of these corn varieties. Their economic substitution will vary based on the nutrient profile compared with regular corn and agronomic considerations.

Currently, high-oil corn is one of the more widely available modified 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.

NutriDense corn is a nutritionally enhanced product containing a stacked set of traits to provide greater nutrient density than conventional yellow dent corn. Specifically, it contains approximately 30 percent more lysine, 50 percent more sulfur amino acids, 18 percent more threonine, almost 34 percent more tryptophan, and 5 percent more energy than normal corn. Because NutriDense corn contains greater levels of amino acids, inclusion of NutriDense corn in the diet reduces soybean meal use and alters the amino acid balance, which should decrease the need for secondary amino acids when high levels of synthetic L-lysine are used.

Distillers Dried Grains With Solubles. With the dramatic increase in ethanol production, distillers dried grains with solubles (DDGS) has become more abundant and available for use in swine diets. When the starch contained in corn is fermented to make ethanol, the by-product is DDGS, which generally contains approximately three times the amount of protein, fiber and oil as corn. Data has indicated that DDGS produced from new ethanol plants has approximately the same energy content as corn; however, concern over palatability and in some studies a reduction in average daily gain limits its inclusion in swine diets. The challenge with DDGS is how to economically evaluate it. If one is extremely conservative, assuming DDGS will result in a reduction in average daily gain and thus a lighter pig at market, then the price of DDGS should be no more than approximately 90 percent the value of corn. If one assumes no differences in pig performance then its value is approximately 120 percent the value of corn. A spreadsheet to help calculate the economics of DDGS is located at *http://www.ksuswine.org*. The following are some additional considerations on using DDGS.

1. DDGS appear to have similar energy (or slightly higher) than corn, so ME value is often not a problem.
2. DDGS lysine availability is variable, but can be dealt with in formulation.
3. When given a choice, pigs prefer to eat a diet that does not contain DDGS.
    a. The negative effect increases as DDGS level increases.
    b. Preference does not change with time on feed.
4. When not given a choice, feed intake is reduced linearly as DDGS level increases in the diet.
    a. The linear reduction in average daily feed intake (ADFI) leads to a linear reduction in ADG and decreased margin over feed.
5. If an individual plant can be identified that is field tested to not have the negative impact on feed intake and the DDGS can consistently be sourced from that plant, DDGS can be an economical ingredient.

6. Concerns over changes in pork quality (soft fat) may limit the inclusion of DDGS in swine diets or at least limit its inclusion in the diets fed right before marketing.
7. Feeding DDGS throughout the entire finishing phase has been shown to reduce carcass yield by approximately 0.50 percent. This decrease in carcass weight needs to be taken into account when evaluating the economic feasibility of using DDGS.

Relative feeding value compared to corn can be used to evaluate the most economical cereal grain energy source (Table 3). This assumes that cost per unit of gain is the most important criteria and assumes that ADG will be similar using the different energy sources. An example to evaluate the feeding value of milo if corn costs 5.0 cents per pound indicates milo is a better value when it costs less than 4.8 (5.0 × 96 percent) cents per pound. The following are general estimates and an in-depth evaluation with help from a nutritionist that should be conducted to determine the actual economic value.

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 as 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. A reduction in the amount of dust will be evident with 1 to 2 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 improvements in average daily gain and feed efficiency (see page 4 for discussion on calculating economics). For every 1 percent of added fat, average daily gain is increased approximately 2 percent in grower diets, and no improvement in average daily gain in late finishing diets for an average of 1 percent. Feed efficiency is usually improved 1.8 percent for each 1 percent increment of added fat in growing–finishing pig diets. Fat is sometimes added to gestation diets strictly for dust control and can be added at 3 to 5 percent in lactation diets to improve milk production.

Table 3. Feeding value of energy feeds compared to corn[a].

Feedstuff	Relative value compared to corn, %
Corn	100
Alfalfa meal, dehydrated	65 to 75
Barley	90 to 95
Dried distillers grains	75 to 112
High lysine corn	110 to 115
High oil corn	110 to 115
Nutridense 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
Soy hulls	60 to 65
Triticale	95 to 105
Wheat	105 to 107
Wheat middlings	90 to 95
Whey, dried	100 to 110

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

Table 4. Typical maximum usage rates for common energy sources[a].

Ingredient	Maximum recommended percent of complete diet[b]				Limitation
	Starter	Grow-finish	Gestation	Lactation	
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
DDGS	5	10	20	5	Amino acid balance and palatability
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
Soy hulls	0	10	20	0	Fiber and bulk density
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

Are there differences in fat sources?

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. Table 5 provides the specific energy contents of different fat sources; these minor differences should be taken into account along with quality concerns when evaluating fat sources. The degree of saturated/unsaturated fatty acids is also listed; this will be a major factor in deciding which fat source to use based on changes in pork quality. 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 0.5 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 (milliequivalents).

More recently the effects of different fat sources on pork quality have become a concern. Pigs will deposit fat in the same fatty acid profile as the dietary fat. Therefore fat sources high in unsaturated fatty acids will produce what is referred to as "soft pork". Soft pork is undesirable because bellies are difficult to slice for bacon; it also increases the incidence of fat "smear" and separation of the different layers of fat in fresh cuts of pork. The degree of saturation is measured by Iodine value, the higher the iodine value the softer the pork. Swine producers should use unsaturated

Table 5. Characteristics and energy values of various sources of fats and oils (data on as-fed basis)[a].

Type of lipid	Total saturated	Total Unsaturated	Iodine value	Energy Content (kcal/lb) DE	ME	NE
Animal fats						
Beef tallow	52.1	47.9	44	3,628	3,483	2,234
Choice white grease	40.8	59.2	60	3,760	3,608	2,311
Lard	41.1	58.9	64	3,757	3,605	2,313
Poultry fat	31.2	68.8	78	3,864	3,710	2,372
Fish oil, menhaden	33.3	66.7	—	3,844	3,689	2,358
Vegetable oils						
Canola (Rapeseed)	7.4	92.6	118	3,973	3,814	2,433
Corn	13.3	86.7	125	3,971	3,812	2,426
Cottonseed	27.1	72.9	105	3,902	3,746	2,392
Peanut	17.8	82.2	92	3,961	3,803	2,426
Soybean	15.1	84.9	130	3,968	3,810	2,431
Sunflower	10.6	89.4	133	3,973	3,814	2,433

[a]From NRC 1998, Nutrient Requirements for Swine.

fat sources with caution if selling to processors that are more sensitive to carcass fat quality.

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, thus feed efficiency will become poorer. Typically average daily gain will usually not be affected, unless the bushel weight drops below 50 pounds per bushel for corn, 45 pounds per bushel for milo and 50 pounds per bushel for wheat. Furthermore, milo with up to 40 percent sprout damage can be effectively utilized by growing–finishing pigs. Many times lower test weight grain, if free of other quality problems, is price discounted more than the reduction in feeding value and provides an opportunity to lower feed cost or capture more value by feeding to pigs.

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 mycotoxin contamination because of high moisture content. Therefore, weather damaged grains should always be screened for suspected mycotoxins 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. There is some evidence that compounds such as bentonite clay and alumniosilicates can improve pig performance when mycotoxin-contaminated grains are fed. However, the cost effectiveness of the these products is difficult to assess.

What are mycotoxins?

Mycotoxins are compounds produced by molds that when consumed by animals or humans will cause 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 6. 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 also has 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. Distillers dried grain with solubles is another ingredient subject to mycotoxin contamination. The mycotoxins will not be inactivated during the fermentation process and will be concentrated due to the removal of the starch. 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 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 located at North Dakota State University (Table 13). 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 6). Also, if possible, feed mytoxin-contaminated grain to later stage finishing pigs or blend with a clean grain source to dilute the impact of the effects.

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. In the past, when formulating diets with commonly available grains and protein sources, the level of crude protein typically used to describe the diet usually contained 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 imperative to specify lysine and other individual amino acid 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

Table 6. 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 T-2 toxin and DAS	Growing/finishing	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[c]	All swine	0.1%	Reduced gain
	Sows, last trimester	0.3%	Reduced piglet birth weight; agalactia
	All swine	0.3%	Gangrene
	All swine	3.0%	Decreased feed consumption
Fumonisins (estimated)	All swine	25 ppm	Minimal changes in clinical chemistry
		50-75	Minimal reduction in feed intake; mild microscopic lesions
		75-100	Reduced feed intake; reduced weight gain; liver damage
		>100	Acute lung edema after 3 to 5 days consumption

[a] Adapted from Mycotoxins, by G. D. Osweller in Diseases of Swine, 9th Ed.
[b] Estimated toxic concentrations are based on literature values.
[c] Concentration of ergot sclerotia in diet.

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 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 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 anti-nutritional 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 overprocessed. Contrary, crystalline or synthetic amino acids are thought to be 100 percent digestible. More and more information about amino acid digestibility is being published for a variety of feed ingredients.

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. True digestibility values will be the most precise in evaluating amino acid digestibility. 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. Because of greater research on amino acid digestibility, especially true ileal digestibility, diets used in the guide are based on true ileal digestible (TID) values.

What are some other common sources of amino acids?

Protein sources are classified into two major categories: animal (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. Furthermore, the actual percentage crude protein in soybean meal from different sources will vary. The source of variation is usually growing conditions affecting the protein content of the soy beans as well as some processing plant-to-plant variation. To adjust for different soybean meal crude protein concentrations and their correlation to the true digestible lysine content the following equation can be used:

% TID lysine = 2.72/46.5 * Actual crude protein

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 true ileal digestible lysine level in the new protein source to soybean meal. For ingredients with different amino acid ratios, the second and third limiting amino acids need to be considered in determining the value of the ingredient. For example, higher levels of synthetic lysine can be used with some ingredients before another amino acid becomes limiting. Thus, valuing the ingredient strictly by the lysine content will underestimate the actual value.

Another factor to consider in selecting amino acid sources is the energy content of the ingredient. Again these ingredients are primarily a source of amino acids, but energy content needs to be a secondary consideration. For example canola meal contains approximately 78 percent the amount of energy as soybean meal. This reduced energy content would be expected to worsen feed efficiency unless extra added fat were added.

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 lists 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.

Some caution is required because feed ingredients may appear to be economical compared to soybean meal, but there are often many "hidden"

Table 7. Typical maximum usage rates for common amino acid sources. [a]

Ingredient	Maximum recommended percent of complete diet[b] Starter	Grow-finish	Gestation	Lactation	Limitation
Alfalfa meal, dehy	0	10	25	0	High fiber
Animal plasma, spray-dried	*	*	*	*	Cost
Blood meal or blood cells, spray-dried	3	5	5	5	Cost, Low isoleucine
Canola meal	0	15	15	15	Anti-nutrition factor
Corn distillers dried grains w/solubles	15	20	30	10	Amino acid balance palatability, pork fat quality
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	*	*	*	*	Cost
Soy protein concentrate	*	*	*	*	Cost
Soy protein isolate	*	*	*	*	Cost
Soybean meal	*	*	*	*	None
Soybean meal, extruded/expelled	*	*	*	*	None
Soybean, full-fat, heat-treated	*	*	*	*	Overheating
Sunflower meal	0	20	*	0	Low energy
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. However the typical prices of the protein source limit their usage.

costs or disadvantages in using these feed ingredients that are not reflected by price. These include energy density, storage costs, anti-nutritional factors, product variability, fiber content, spoilage, and underprocessing or overprocessing. 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.

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 25 percent of the soybean meal or protein supplement in the diet. At this inclusion rate, it is unlikely that the total diet will contain more than 0.01 percent free gossypol. Pig performance begins to be reduced at gossypol concentrations of 0.04 percent of the diet. Solvent extracted, gossypol-free cottonseed meal can be used to replace 50 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-based diets may also need supplemental biotin because it is unavailable. Canola meal can be used to replace up to 25 percent of the protein from soybean meal in nursery diets, 50 percent of the soybean meal in growing pigs and lactation diets, and the entire protein source in gestation and late finishing 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. Because 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 50 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, spray-dried blood meal and spray-dried blood cells are by-products of blood obtained from swine and cattle processing plants. Previously, spray-dried animal plasma has been used 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 78 percent protein and 6.43 percent TID 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 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, appear to have similar nutritional value in starter diets as spray-dried blood meal except that it is slightly higher in crude protein and lysine. When adding spray-dried blood products to starter diets, dietary methionine levels must be checked because these ingredients are low in methionine. Synthetic methionine usually needs to be added to starter diets containing either spray-dried animal plasma, blood meal, or red blood cells. When using blood meal or cells, care must be taken to ensure the isoleucine concentration does not become deficient.

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 (1.25 percent TID lysine percent). Amino acid supplemented starter diets containing spray-dried wheat gluten may be used as a replacement for soybean meal or dried skim milk in starter diets.

Soy Protein Concentrate. Soy protein concentrate contains approximately 65 to 70 percent protein and approximately 3.99 percent TID 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 insolubilized 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. Varieties of soybeans exist that have one of the trypsin inhibitors (Kunitz inhibitor) genetically selected against, which allows for greater use in growing pig diets. However, research shows that some heat treatment of low Kunitz inhibitor soybeans is required for maximum utilization.

Field Peas. Field peas contain 22 to 29 percent crude protein and 1.32 percent TID lysine. They are a good source of lysine but relatively low in methionine and tryptophan. They also contain a relatively high concentration of energy because of the high concentration of starch. Like raw soybeans, field peas contain the anti-nutritional factor, trypsin inhibitor. The trypsin inhibitor concentration can be deactivated by heating, but it is usually in low enough concentrations not to worry about in diet formulation. Data suggest that field peas can be included up to 15 percent of the diet in starter diets and replace all of the soybean meal in finishing pig diets as long as adequate methionine and tryptophan concentrations are maintained.

Full-fat soybeans. If properly done, on-farm processing by roasting or extruding raw soybeans results in excellent sources of protein. On-farm roasting or extruding yield "full-fat" soybeans, which, in some instances, are a relatively low-cost 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 lysine 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.

Extruded/expelled soybean meal. Extruded expelled soybean meal is made when raw soybeans are extruded, then the oil is squeezed out (expelled) producing a soybean meal with approximately 5 percent fat compared to the 1 percent fat in solvent-extracted soybean meal. Studies have shown that extruded expelled soybean meal has slightly higher digestibility of amino acids and greater energy than solvent extracted soybean meal. Therefore producers can afford to pay more for extruded/expelled soybean meal than solvent extracted soybean meal. Extruded expelled soybean meal can replace all of the soybean meal in nursery, grow-finish, and sow diets. The only concern with its use is whether it is properly processed to deactivate the trypsin inhibitors and the correct dry matter and lysine content are used in diet formulation.

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.

Are synthetic amino acids an option in diet formulation?

Synthetic amino acids, if added properly, can reduce feed costs and maintain pig performance. Lysine, threonine, and methionine are three feed-grade amino acids most commonly added 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, 93 pounds of 46.5 percent crude protein soybean meal can be replaced by the addition of 3 pounds L-lysine HCl and 90 pounds grain per ton. If the 3 pounds L-lysine HCl and 90 pound grain are cheaper than 93 pounds of

46.5 percent crude protein soybean meal, the diet costs would be reduced by using supplemental lysine. In some cases it may be economical to feed greater than 3 pounds per ton of synthetic lysine; however, in these cases synthetic methionine and threonine must be added to most corn-soybean meal-based diets. It is imperative that you consult your nutritionist when using greater than 3 pounds per ton.

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 can result in deficiencies of other amino acids which will reduce litter weaning weights. The exception may be in diets for first parity sows where 0.1 percent L-lysine HCl is often added to meet the high dietary lysine requirement of young sows during lactation.

What is a calorie:protein ratio?

In diets for most growing pigs, as the energy density of the diet increases, growth rate increases. When this happens a higher dietary lysine percentage is required to maintain a similar lysine intake (grams/day). The ratio of energy in the diet needs to remain proportional to the amount of lysine. This is called a lysine:calorie ratio. Thus, the lysine to calorie ratio is used to ensure the right amount of lysine is provided in diets that vary in energy density. In most cases in diet formulation, we select the most economical energy density of the diet, then use a lysine:calorie ratio to establish lysine concentrations of the diet. General guidelines for amino acid fortifications as well as proposed calorie:lysine ratios can be found in the factsheets on *Starter Pig Recommendations*, MF-2300; *Growing–Finishing Pig Recommendations*, MF-2301, and *Breeding Herd Recommendations for Swine*, MF-2302. They can be found at *www.ksuswine.org*.

What is an "amino acid ratio"?

Lysine is generally the first limiting amino acid in most corn-soybean meal-based diets. However it is important that the other amino acids are present in the diet at their proper concentrations to provide optimum protein synthesis. An amino acid ratio is a means of determining the requirement for an amino acid relative to the amount of lysine in the diet. For example, threonine in finishing diets should be 62 percent the amount of lysine in the diet. Therefore if a diet contains 1.0 percent lysine, the threonine content should be at least 0.62 percent. If the amount of lysine changes, the amount of threonine (and other amino acids as well), should change in proportion to lysine. The use of an amino acid ratio makes establishing requirements for other amino acids relatively easy. The challenge is that there is much debate as to the correct ratio to use. Recommended ratios for the key amino acids relative to lysine can be found in the factsheets on Starter Pig Recommendations, Growing–Finishing Pig Recommendations, and Breeding Herd Recommendations for Swine. They can be found at *www.ksuswine.org*.

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

Compared with gilts, barrows will grow faster, but have poorer feed efficiency and can be slightly fatter at market. 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 them separately. One option to simplify split sex feeding is to use the same diets and feed budget for barrows and gilts. Because barrows will consume more feed as a result of being slightly less efficient, they will switch diets sooner and at lighter weights than gilts. This will result in both barrows and gilts more closely matching their protein deposition curves with dietary lysine and energy concentrations. If gilts are to be retained in the breeding herd, their diets can be fortified with extra calcium and phosphorus for bone development. Marketing programs may take advantage of split sex feeding in barn close-outs because of differences in growth rates among gilts and barrows.

A second option for producers may want to use instead of split-sex feeding is to feed based on initial weight of pigs going into the barn. In this situation (separate bins and feed lines must be available) the heaviest pigs would be penned on one side of the barn with the lightest half on the other. Research has shown that feeding high fat diets to the light half and no added fat to the heavy half, the number of light weight pigs sold can be reduced and margin over feed costs can be increased. Additional information and suggested lysine levels are listed in Growing–Finishing Pig Recommendations, which can be found at *www.ksuswine.org*.

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 and thus energy intake. The reduction in energy intake will in turn decrease average daily gain. If pigs are not growing as fast, this will decrease lysine requirements. Increasing dietary lysine in the diet will not offset the reduction in average daily gain because there will not be enough energy available to fuel protein synthesis. Therefore, we do not recommend changing diets based on season of the year. By maintaining a calorie:lysine ratio, the balance between these two nutrients will be maintained even when feed intake is reduced. In the summer months, it is advisable to provide drip cooling, or some other method to keep pigs cool and feed intake high.

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.

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.

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 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, a calcium and phosphorus deficiency will result in impaired bone mineralization, reduced bone strength, and poor growth. Young pigs with a calcium and phosphorus deficiency 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 is available phosphorus?

Approximately 50 to 70 percent of the phosphorus contained in plant products is in a form that is unavailable to the pig. A range of 8 to 60 percent of phosphorus availability has been reported in cereal grains. Feeds of animal origin, such as meat and bone meal, or fish meal, are quite high in calcium and available phosphorus. 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. In the past we formulated diets based on a "total" phosphorus basis and provided a large margin of safety above the pig's requirement in the diet. Today with greater concern about the phosphorus content of swine manure, nutritionists have moved to formulating with available phosphorus values in feed ingredients. Using available phosphorus values in diet formulation can more precisely meet the pig's requirements and reduce phosphorus excretion in waste.

What is the enzyme phytatase?

Phytase is an enzyme that when added to a swine diet increases the digestibility of phytate phosphorus. Depending on the amount of phytase added to the diet, phosphorus digestibility can be increased 20 to 70 percent compared with diets without phytase. Therefore adding phytase to the diet can greatly reduce the amount of inorganic phosphorus (mono- or dicalcium phosphate) added to the diet. This greatly reduces the amount of phosphorus excreted in swine waste. There are now several sources of phytase available listed in the KSU Vitamin Premix Recommendations at: *www.ksuswine.org*.

What are the preferred 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.

The standard ingredient for supplying supplemental calcium is limestone. Phosphorus is primarily supplied by dicalcium phosphate or monocalcium phosphate. Table 8 lists a number of additional feed ingredients that may be used to supply calcium and phosphorus. Preferred sources of Ca and P are also listed in bold text. It should be noted that many of the sources supply both calcium and phosphorus, so the quantity of limestone in the diet also must 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.

How can I determine which is the lowest cost source of phosphorus?

Phosphorus is the 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 $18 per 100 pounds and monocalcium phosphate (18 percent calcium, 21 percent phosphorus) is $20 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,18% P
18¢ per lb /.18 = $1.00/lb P
Monocalcium phosphate, 21% P
20¢ per lb /.21 = $0.95/lb

Therefore, the monocalcium phosphate would be a cheaper source of phosphorus.

The second consideration when pricing phosphorus is the freight charge. Transporting a more concentrated source of an ingredient, in this case monocalcium phosphate, may offset any difference in price between it and dicalcium phosphate. The same principle would apply to any ingredient that may vary in concentrations; the more concentrated product may be less expensive based on freight charges.

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 phospho-

Table 8. Mineral concentrations in macro mineral sources (data on as-fed basis)[a].

Ingredient	Calcium (%)	Phosphorus (%)	Phosphorus Bioavailability (%)
Bone meal, steamed	29.80	12.50	80 to 90
Calcium carbonate	38.50	0.02	–
Calcium phosphate (dicalcium)	**20 to 24**	**18.50**	**95 to 100**
Calcium phosphate (monocalcium)	**18.00**	**21.10**	**100**
Calcium sulfate, dehydrate	21.85	–	–
Limestone, ground	**38.00**	**0.01**	–
Phosphate, defluorinated	32.00	18.00	85 to 95
Phosphate, monoammonium	0.35	24.30	100
Phosphate, rock curacao, ground	35.09	14.23	40 to 60
Phosphate, rock, soft	16.09	9.05	30 to 50
Sodium phosphate, dibasic	–	21.15	100
Sodium phosphate, monbasic	0.09	24.94	100

[a]From NRC 1998, Nutrient Requirements for Swine, 10th Ed. Bold font indicates preferred sources of Ca and P to be used in diet formulation. Note, the mineral supplements used as feed supplements are not chemically pure compounds, and the composition may vary substantially among sources. The supplier’s analysis should be used if it is available. For example, feed-grade dicalcium phosphate contains some monocalcium phosphate and feed-grade monocalcium phosphate contains some dicalcium phosphate. Dashes indicate that data were unavailable.

rus, the following example may be helpful:

1. The diet has 30 pounds of monocal (21% P; 18% Ca) and 10 pounds 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 mono cal.
   b. 6.3 pounds ÷ 18% = 35 pounds of dical (18% P) needed to replace 30 pounds 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. 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 can 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. Calcium and available phosphorus levels for replacement gilts should be approximately 0.1 percent higher than those fed to normal finishing pigs.

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.

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 0.5 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 0.2 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 Board 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. 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. Selenium and(or) vitamin E deficiency results in increased incidence of mulberry heart disease; therefore, 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 (0.27 g/ton) for all pigs. Research has demonstrated that higher serum and tissue levels of selenium can be achieved by adding organic selenium to the diet.

Should I add chromium to my sow diets?

Several studies have observed increased farrowing rate or number of pigs born to sows fed chromium in finishing and gestation and lactation. Based on these findings, chromium is included in the sow add pack at the maximum legal addition of 200 ppb chromium (KSU Vitamin Premix Recommendations at: *www.ksuswine.org*). Chromium must be added in a chelated form to be utilized by the pig.

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 byproducts. 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 KSU Vitamin Premix Recommendations at: *www.ksuswine.org*. 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. With fewer ingredients used in diet formulation, there is no longer the variety of feed ingredients to supply added vitamins. In addition, 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

Table 9. Inorganic sources and estimated bioavailabilities of trace minerals[a].

Mineral Element and Source[b]	Chemical Formula	Mineral Content (%)	Relative Bioavailability (%)
Copper			
Cupric sulfate (pentahydrate)	$CuSo_4•5H_2O$	25.2	100
Cupric chloride, tribasic	$Cu_2(OH)_3Cl$	58.0	100
Cupric oxide	CuO	75.0	0 to 10
Cupric carbonate (monohydrate)	$CuCO_3•Cu(OH)_2•H_2O$	50 to 55	60 to 100
Cupric sulfate (anhydrous)	$CuSO_4$	39.9	100
Iron			
Ferrous sulfate (monohydrate)	$FeSO_4•H_2O$	30.0	100
Ferrous sulfate (heptahydrate)	$FeSO_4•7H_2O$	20.0	100
Ferrous carbonate	$FeCO_3$	38.0	15 to 80
Ferric oxide	Fe_2O_3	69.9	0
Ferric chloride (hexahydrate)	$FeCl_3•6H_2O$	20.7	40 to 100
Ferrous oxide	FeO	77.8	–[b]
Iodine			
Ethylenediamine dihydroiodide (EDDI)	$C_2H_8N_22HI$	79.5	100
Calcium iodate	$Ca(IO_3)_2$	63.5	100
Potassium iodide	KI	68.8	100
Postassium iodate	KIO_3	59.3	–[b]
Cupric iodide	CuI	66.6	100
Manganese			
Manganous sulfate (monohydrate)	$MnSO_4•H_2O$	29.5	100
Manganous oxide	MnO	60.0	70
Manganous dioxide	MnO_2	63.1	35 to 100
Manganous carbonate	$MnCO_3$	46.4	30 to 100
Manganous chloride (tetrahydrate)	$MnCl_2•4H_2O$	27.5	100
Selenium			
Sodium selenite	Na_2SeO_3	45.0	100
Sodium selenate (decahydrate)	$Na_2SeO_4•10H_2O$	21.4	100
Zinc			
Zinc sulfate (monohydrate)	$ZnSO_4•H_2O$	35.5	100
Zinc oxide	ZnO	72.0	50 to 80
Zinc sulfate (heptahydrate)	$ZnSO_4•7H_2O$	22.3	100
Zinc carbonate	$Zn•CO_3$	56.0	100
Zinc chloride	$ZnCl_2$	48.0	100

[a] From NRC, 1998 Nutrient Requirements of Swine 10th Ed. The mineral sources listed in bold font are preferred sources. Chelated forms of these minerals can also be used in diet formulation and their relative bioavailability is close to 100%.
[b] Data unavailable.

mineral levels as "added" levels. This helps to eliminate some of the confusion and difficulty in determining availability and concentrations in feed ingredients.

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 that 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 KSU Vitamin Premix Recommendations at: *www.ksuswine.org*. 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?

A natural source of vitamin E, d-alpha tocopherol, derived from soybean oil is available for use in swine diets. It differs with synthetic vitamin E because synthetic is a mixed tocophol containing both D and L forms of alpha tocopherol (dl-alpha tocopherol). The L form of tocopherol is not available to pigs and therefore dl alpha tocopherol has a lower potency than natural or d-alpha tocopherol. Although research on the potency of natural vitamin E will vary, it is generally assumed that it contains 1.26 times the availability of synthetic vitamin E. Therefore if the price of natural vitamin E is less than 1.26 times the price of synthetic vitamin E, the natural source will be a better value. When formulated on an equal potency value, there are no differences in pig performance when fed either source.

Premix recommendations

A suggested vitamin premix is listed in KSU Vitamin Premix Recommendations at: *www.ksuswine.org*. 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. As an option for producers, we have also included a concentrated vitamin premix. This is identical to the existing vitamin premix, only it has half the inclusion rate. Frequently producers ask about the possibility of a combined vitamin and trace mineral premix. We discourage the use of combined vitamins and trace minerals because the addition of trace minerals to a vitamin premix will greatly reduce its shelf-life, especially if the vitamin premix contains phytase. If you use combined vitamin/trace mineral premixes, the age of the premix needs to be closely monitored to use the product before vitamin stability becomes an issue.

Base mix recommendations

Because feed processing systems differ from farm to farm, several base mix recommendations have been included in the factsheet, KSU Base mix Recommendations at: *www.ksuswine.org*, 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. In addition, because choline, trace minerals (basemixes), and 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

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 B12	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. Stability of various vitamin forms[a].

Vitamin and form	Percentage vitamin loss per month of storage			
	Premix w/o Choline	Premix w/ Choline	Base Mix	Pellet + Extruded
A beadlet, cross linked	0.8	2.0	4.2	8.0
A beadlet, non cross linked	2.9	8.1	20.0	30.0
D_3 beadlet (A/D_3) cross linked	0.6	1.1	3.3	4.0
D_3 spray-dried	1.6	2.0	5.0	12.0
E acetate 50%	0.2	0.3	4.0	2.9
E alcohol, natural	35.0	40.0	70.0	40.0
MSBC	0.6	9.0	17.0	17.0
MSB coated	0.04	5.4	9.0	11.0
MSB	1.0	13.0	35.0	23.0
MNB	0.04	5.0	10.0	11.0
MPB	0.04	8.0	13.0	12.0
Thiamine HCL	0.7	7.1	12.2	4.0
Thiamine Monohydrochloride	0.04	2.9	8.1	4.5
Riboflavin	0.04	2.6	9.0	2.0
Pyridoxine	0.04	3.0	8.2	2.9
B_{12}	0.04	0.3	4.2	2.9
Calcium Pantothenate	0.04	2.4	3.0	1.8
Folic Acid	0.04	3.6	9.2	4.5
Biotin	0.04	1.5	4.7	2.4
Niacin	0.04	2.2	3.5	2.4
Niacinamide	0.08	3.0	4.0	4.2
Ascorbic Acid	1.8	11.0	25.0	37.0
Cellulose coated Ascorbic	1.8	10.0	20.0	30.0
Fat coated Ascorbic	0.9	2.9	13.0	17.0
Choline	---	0.2	2.0	1.0

[a]From BASF, Vitamin Nutrition for Swine 2001

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 60,000 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, especially in newly born pigs, 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. Menadione dimethylpyrimidinol bisulfite (MPB) or menadione nicotinamide bisulfite (MNB) are two potential sources of vitamin K. Both sources contain approximately 45 percent menadione and equal potency; however MNB is a much more stable source of vitamin K and a preferred source in base mixes.

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 and influence muscle fiber development in fetuses of gestating sows. Like chromium, L-carnitine has been added to the recommendations to the sow vitamin premix.

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. Although not entirely conclusive, some research has demonstrated increased number of pigs born to sows fed added pyridoxine. Therefore, 4.5 g/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 one pig per litter.

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 requirements. 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?

Research has shown that pigs will take longer to drink when water flow rate is reduced. Low

Table 12. Recommended water flow rates.

	Pig Weight Range, lb				
	< 12 lb	12 to 30	30 to 75	75 to 150	150 to market
Height, in.	4 to 6	6 to 12	12 to 18	18 to 24	24 to 30
Pigs/nipple	10	10	10	12 to 15	12 to 15
Flow rate, cups/min	2/3	1	1.5	2	3
Seconds to fill a 16 oz bottle	180	120	80	60	40
Daily use, quarts	0.2 to 0.5	2 to 4	4 to 6	5 to 10	6 to 18

Iowa State University PM-1493, 1992.

water flow rate will also negatively affect growing-finishing pig performance. Generally it is recommended to have a single waterer for every 10 to 15 pigs. Suggested water flow rates, number of nipple waterers per pig and nipple height based on phase of production are listed in Table 12. The number of pigs per waterer can be increased slightly when using a cup or bowl-type drinker.

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 in the feeders. 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 impair 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 (TDS) measures minerals that contribute to the salinity of the water, such as sodium chloride, and calcium and magnesium salts. High TDS may reduce 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 details on specific areas of feed manufacturing, the Feed Quality Assurance Handbook offered through the Department of Grain Science and Industry and the NPPC Feed Purchasing Manual are recommended references.

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, can be 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 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 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, moving from complete feed to a premix program increases diet flexibility. Diets can be specifically formulated to fit the operation, facilities, genetics and environment. Probably the biggest advantage to 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 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 hammer mill 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 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.

Should I process my feed with a hammer mill 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. Hammer mills can change from grinding one grain to another by changing screens. However, a hammer mill 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 hammer mill, but if grain types are to be changed frequently, the roller mill will need to be adjusted for each grain. One major difference between hammer mills and roller mills is the uniformity of ground particles produced. A roller mill will produce grain with a much more uniform particle size than a hammer mill. The more uniform the particle, the better feed will flow through augers, bins, and feeders. For example, a roller mill ground corn with 6 percent added fat will have the same flow ability as hammer milled ground grain without added fat. The problem with feed bridging in bins and feeders is a significant one, and therefore a roller mill may be a better alternative to a hammer mill for feed processing.

For processing grain with a hammer mill, screen size will vary based on type of grain. Corn and wheat may be processed through a hammer mill 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:

- 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;
- The rolls should have corrugations to help slice the grain, with 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;
- The corrugations should have a 1- to 2-inch spiral to increase 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 hammer mills 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 of pelleting must be offset by improved feed efficiency.

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 homegrown 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 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, feed cost per pound of gain, or in instances when ADG will also be improved, margin over feed costs should be used.

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 responsibility for mixing feed. This generally reduces 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 added responsibility for 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 is included in the fact sheet, *Growing–Finishing Pig Recommendations, MF-2301* found at *www.ksuswine.org*.

By multiplying 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 compare cost between feeding programs. Comparing these values to 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 overfeeding one phase and underfeeding another.

In addition to particle size reduction, the producer must also be concerned about whether or not 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 of mixing time per batch of feed. Tests have shown that overfilling mixers greatly increases the amount of time needed for mixing. Worn ribbons and screws will also require 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 percent). 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 aflatoxins) 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 or spray-dried blood cells 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, a complete mineral analysis (Ca, P, Fe, Zn, Mn, Cu, and NaCl) once per year 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 unsaponafiables) 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 calculated nutrient composition and compare it to those suggested by Kansas State University.
3. Check diets frequently. Again, check the tonnage used by each phase of production to make sure you are not overfeeding or underfeeding a diet. Also, continually check prices of your diets and cost per cwt. (hundredweight) of pork sold.
4. Request a mill sheet of the diet you have purchased. A mill sheet is the actual formulation the feed mill uses to mix the batch of feed. Mill sheets can be helpful in determining if ingredients have been substituted or missing from a formulation.

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 nonrepresentative 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, 1/2-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 one 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. Examples are provided in the KSU Vitamin Premix Recommendations at: *www.ksuswine.org*.
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.

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 13. 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 sample size, 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 14). 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 2001 K-State Research and Extension Publication MF-2037; *www.bookstore.ksre.ksu.edu/pubs/MF2037.pdf*.

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 Tables 15, 16, 17, and 18. Values are derived from the 1998 NRC Nutrient Requirements for Swine, 10th Ed. unless otherwise indicated.

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 13. Commercial laboratories performing feed ingredient and finished feed analyses[a].

A & L Analytical Lab, Inc.
2790 Whitten Road
Memphis, TN 38133
(800) 264-4522
(901) 213-2400
www.al-labs.com

Barrow-Agee Laboratories
1555 Three Place
Memphis, TN 38116
(901) 332-1590
www.balabs.com

CII Laboratory Inc.
10835 Ambassador Drive
Kansas City, MO 64153
(816) 891-7337
www.ciilab.com

Colorado Analytical Laboratory
P.O. Box 507
Brighton, CO 80601
(303) 659-2313
www.coloradolab.com

Eurofins Scientific, Inc.
3507 Delaware
Des Moines, IA 50313
(515) 265-1461
www.eurofinsus.com

Iowa Testing Lab
Highway 17 North
P.O. Box 188
Eagle Grove, IA 50533
(800) 274-7645
(515) 448-4741
www.iowatestinglabs.com

Midwest Laboratories, Inc.
13611 B Street
Omaha, NE 68144-3693
(402) 334-7770
www.midwestlabs.com

Ralston Analytical Laboratories
Checkerboard Square
St. Louis, MO 63164
(800) 423-6832
(314) 982-1310
www.ralstonanalytical.com

Romer
1301 Stylemaster Dr.
Union, MO 63084-1156
(636) 583-8600
(636) 583-6553 FAX
www.romerlabs.com

SDK Laboratories, Inc.
1000 Cory Rd.
Hutchinson, KS 67501
(877) 464-0623
(620) 665-5661
www.sdklabs.com

Servi-Tech
1816 East Wyatt Earp
P.O. Box 1397
Dodge City, KS 67801
(800) 557-7509
(620) 227-7123
www.servi-techinc.com

Servi-Tech
1602 Park West Drive
P.O. Box 169
Hastings, NE 68902
(800) 557-7509
(402) 463-3522
www.servi-techinc.com

Department of Veterinary Diagnostic Services
(mycotoxins only)
North Dakota State University
17 Van Es Hall
Fargo, ND 58105
(701) 231- 8307
www.vdl.ndsu.edu

Ward Laboratories Inc.
4007 Cherry Ave.
P.O. Box 788
Kearney, NE 68848
(800) 887-7645
(308) 234-2418
www.wardlab.com

[a]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 sample size, methods, and mailing.

Table 14. Permitted analytical variations (AV) based on AAFCO check sample programs.

Analysis	Determination method[a]	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%
Lysine	975.44	20	.5-4%
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	927.02 968.02	(14/x + 6) 10 12	5–25% 10–25% < 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 30	.03–1% < .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 ICP	20 15	.2 - 4% .2 - 4%
Vitamin A	974.29	30	1200–218,000 IU/lb
Vitamin B12	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. Form more information see Herrman, 2001 K-State Research and Extension Publication MF-2037; *www.bookstore.ksre.ksu.edu/pubs/MF2037.pdf.*

Table 15. Chemical composition of some feed ingredients commonly used in swine diets (as-fed basis)[a].

Ingredient	ME, kcal/lb	Protein, %	Ca, %	P, %	Availability of P, %	Avail P, %	Ether extract, %	Linoleic acid, %	Crude fiber, %	Phytase, FTU/lb	Iodine value
Alfalfa meal, dehy	748	17.00	1.53	0.26	100	0.26	2.6	0.35	25.7	---	32.5
Bakery byproduct	1,678	10.80	0.13	0.25	20	0.05	11.3	5.7	---	---	141.25
Barley	1,320	10.50	0.06	0.36	30	0.11	1.9	0.91	4.6	---	19
Beef tallow	3,483	---	---	---	---	---	100	3.1	---	---	440
Calcium chloride	---	---	27.3	---	100	---	---	---	---	---	---
Canola meal	1,197	35.60	0.63	1.01	21	0.21	3.5	0.42	12.4	---	43.75
Choice white grease	3,608	---	---	---	---	---	100	11.6	---	---	600
Corn	1,551	8.50	0.03	0.28	14	0.04	3.9	1.92	2.2	---	48.75
Corn starch	1,807	---	---	---	---	---	---	---	0.2	---	---
DairyLac 80 or deproteinized whey	1,497	5.00	0.5	0.6	97	0.61	0.2	---	---	---	0.88
DDGS	1,551	27.20	0.03	0.71	77	0.55	10.7	6.3	7.3	---	134
Developer base mix	---	---	19.6	10.0	100	1.0	1.0	---	---	---	12.5
Dicalcium phosphate, 18.5% P	---	---	21.00	18.50	100	18.50	---	---	---	---	---
DL-Methionine	2,426	58.40	---	---	---	---	---	---	---	---	---
Dried skim milk	1,685	34.60	1.31	1.00	91	0.91	0.9	---	0.2	---	3.96
Extruded expelled soybean meal	1,743	46.50	0.34	0.69	23	0.16	6.5	3.32	3.9	---	84.5
Extruded soy protein concentrate	1,587	64.00	0.35	0.81	23	0.19	3.0	1.5	---	---	39
Grow-finish base mix	---	---	21.5	4.8	100	4.80	1.0	---	---	8,160	12.5
Hard red winter wheat	1,456	13.50	0.06	0.37	50	0.19	2.0	0.93	2.2	---	25
High oil corn	1,621	9.01	0.03	0.30	14	0.04	8.0	4.72	---	---	100
Hominy Feed	1,456	10.30	0.04	0.43	14	0.06	6.7	2.97	5.5	---	83.75
Lactose	1,558	---	---	---	---	---	---	---	---	---	---
Limestone	---	---	38.00	---	---	---	---	---	---	---	---
L-Threonine	1,710	73.10	---	---	---	---	---	---	---	---	---
L-Tryptophan	2,798	85.30	---	---	---	---	---	---	---	---	---
Lysine HCl	1,968	95.40	---	---	---	---	--	---	---	---	---
Meat and bone meal	1,009	51.50	9.99	4.98	90	4.48	10.9	0.72	---	---	69.76
Methionine hydroxy analog	2,145	---	---	---	---	---	---	---	---	---	---
Milo	1,515	9.20	0.03	0.29	20	0.06	2.9	1.13	2.4	---	34.8
Monocalcium phosphate, 21% P	--	---	18.50	21.00	100	21.00	---	---	---	---	---
Peas	1,456	22.80	0.11	0.39	21	0.08	1.2	0.47	5.2	---	15
Potassium chloride	---	---	---	---	100	---	---	---	---	---	---

Table 15, continued

Poultry meal	1,297	64.10	4.46	2.41	90	2.17	12.6	2.54	---	---	98.28
Pulverized oat groats	1,571	13.90	0.08	0.41	13	0.05	6.2	2.4	4.0	---	77.5
Restaurant grease	3,721	---	---	---	---	---	100	17.5	---	---	750
Select menhaden fish meal	1,524	62.90	5.21	3.04	94	2.86	9.4	0.12	---	---	70.5
Sow add pack	---	---	---	---	---	---	---	---	---	---	---
Sow base mix	---	---	21.00	9.20	100	9.20	1	---	---	9,070	---
Soy hulls	1,001	12.10	0.54	0.16	30	0.05	2.2	1.11	34.2	---	27.5
Soybean meal, 44% CP	1,442	43.80	0.32	0.65	31	0.20	1.5	0.69	6.0	---	19.5
Soybean meal, 46.5% CP	1,533	46.50	0.34	0.69	23	0.16	1.5	0.6	3.9	---	18.75
Soybean oil	3,810	---	---	---	---	---	100	51	---	---	1,300
Soybeans, full fat	1,673	35.20	0.25	0.59	31	0.18	18	9.13	5.2	---	234
Spray dried whey	1,447	12.10	0.75	0.72	97	0.70	0.9	1.1	---	---	3.96
Spray-dried blood cells	1,336	92.00	0.02	0.37	92	0.34	1.3	0.17	---	---	5.72
Spray-dried blood meal	1,336	88.80	0.41	0.30	92	0.28	1.3	0.17	---	---	5.72
Spray-dried animal plasma	1,767	78.00	0.15	1.71	92	1.57	---	---	---	---	---
Starter base mix	---	---	17.00	6.60	100	6.60	1.0	---	---	10,460	---
Trace mineral premix	---	---	---	---	---	---	---	---	---	---	---
Vitamin premix with phytase	---	---	---	---	---	---	---	---	---	136,000	---
Wheat bran	1,032	15.70	0.16	1.20	29	0.35	4.0	1.8	9.2	---	50
Wheat middlings	1,372	15.90	0.12	0.93	41	0.38	4.2	1.7	7	---	52.5

[a] Adapted from NRC (1998), 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.).

Table 16. Total amino acid composition of some feed ingredients commonly used in swine diets (as-fed basis)[a].

Ingredient	Lysine	Isoleucine	Leucine	Methionine	Cysteine	Threonine	Tryptophan	Valine
Alfalfa meal, dehy	0.74	0.68	1.21	0.03	0.18	0.70	0.24	0.86
Bakery byproduct	0.27	0.38	0.80	0.18	0.23	0.33	0.10	0.46
Barley	0.36	0.37	0.68	0.17	0.20	0.34	0.13	0.49
Beef tallow	---	---	---	---	---	---	---	---
Calcium chloride	---	---	---	---	---	---	---	---
Canola meal	2.08	1.43	2.58	0.74	0.91	1.59	0.45	1.82
Choice white grease	---	---	---	---	---	---	---	---
Copper sulfate	---	---	---	---	---	---	---	---
Corn	0.26	0.28	0.99	0.17	0.19	0.29	0.06	0.39
Corn starch	---	---	---	---	---	---	---	---
DairyLac 80 or deproteinized whey	0.20	0.13	0.22	0.04	0.05	0.13	0.13	0.13
DDGS	0.78	1.01	3.17	0.55	0.55	1.06	0.21	1.35
Developer base mix	3.14	---	---	---	---	---	---	---
Dicalcium P, 18.5% P	---	---	---	---	---	---	---	---
DL-Methionine	---	---	---	99.00	---	---	---	---
Dried skim milk	2.86	1.87	3.67	0.92	0.30	1.62	0.51	2.33
Extruded expelled soybean meal	3.02	2.16	3.66	0.67	0.74	1.85	0.65	2.27
Extruded soy protein concentrate	4.20	3.30	5.30	0.90	1.00	2.80	0.90	3.40
Grow-finish base mix	5.24	---	---	---	---	---	---	---
Hard red winter wheat	0.34	0.41	0.86	0.20	0.29	0.37	0.15	0.54
High oil corn	0.30	0.27	1.14	0.19	0.20	0.32	0.06	0.45
Hominy feed	0.38	0.36	0.98	0.18	0.18	0.40	0.10	0.52
Lactose	---	---	---	---	---	---	---	---
Limestone	---	---	---	---	---	---	---	---
L-Threonine	---	---	---	---	---	99.00	---	---
L-Tryptophan	---	---	---	---	---	---	98.50	---
Lysine HCl	78.60	---	---	---	---	---	---	---
Meat and bone meal	2.51	1.34	2.98	0.68	0.50	1.59	0.28	2.04
Methionine hydroxy analog	---	---	---	88.00	---	---	---	---
Milo	0.22	0.37	1.21	0.17	0.17	0.31	0.10	0.46
Monocalcium phosphate, 21% P	---	---	---	---	---	---	---	---
Peas	1.50	0.86	1.51	0.21	0.31	0.78	0.19	0.98
Potassium chloride	---	---	---	---	---	---	---	---

Table 16, continued

Poultry meal	3.32	2.01	3.89	1.11	0.65	2.18	0.48	2.51
Pulverized oat oroats	0.48	0.55	0.98	0.20	0.22	0.44	0.18	0.72
Restaurant grease	---	---	---	---	---	---	---	---
Salt	---	---	---	---	---	---	---	---
Select menhaden fish meal	4.81	2.57	4.54	1.77	0.57	2.64	0.66	3.03
Sow add pack	---	---	---	---	---	---	---	---
Sow base mix	---	---	---	---	---	---	---	---
Soy hulls	0.89	0.52	0.87	0.17	0.23	0.47	0.06	0.49
Soybean meal, 44% CP	2.83	1.99	3.42	0.61	0.70	1.73	0.61	2.06
Soybean meal, 46.5% CP	3.02	2.16	3.66	0.67	0.74	1.85	0.65	2.27
Soybean oil	---	---	---	---	---	---	---	---
Soybeans, full fat	2.22	1.61	2.75	0.53	0.55	1.41	0.48	1.68
Spray dried whey	0.90	0.62	1.08	0.17	0.25	0.72	0.18	0.60
Spray-dried blood cells	8.51	0.49	12.70	0.81	0.61	3.38	1.37	8.50
Spray-dried blood meal	7.45	1.03	10.81	0.99	1.04	3.78	1.48	7.03
Spray-dried animal plasma	6.84	2.71	7.61	0.75	2.63	4.72	1.36	4.94
Starter base mix	7.26	---	---	5.21	---	4.26	---	---
Trace mineral premix	---	---	---	---	---	---	---	---
Vitamin premix with phytase	---	---	---	---	---	---	---	---
Wheat bran	0.64	0.49	0.98	0.25	0.08	0.52	0.22	0.72
Wheat middlings	0.57	0.53	1.06	0.26	0.32	0.51	0.20	0.75

[a] Adapted from NRC (1998), 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.).

Table 17. True ileal digestibility (TID) percentages of amino acids in some feed ingredients commonly used in swine diets (as-fed basis) [a].

	True Digestibility of amino acids, %							
Ingredient	Lysine	Isoleucine	Leucine	Methionine	Cystine	Threonine	Tryptophan	Valine
Alfalfa meal, dehy	56%	68%	71%	71%	37%	63%	46%	64%
Bakery byproduct	0%	0%	0%	0%	0%	0%	0%	0%
Barley	79%	84%	86%	86%	86%	81%	80%	82%
Beef tallow	---	---	---	---	---	---	---	---
Calcium chloride	---	---	---	---	---	---	---	---
Canola meal	78%	78%	81%	86%	83%	76%	75%	77%
Choice white grease	---	---	---	---	---	---	---	---
Copper sulfate	---	---	---	---	---	---	---	---
Corn	78%	87%	92%	90%	86%	82%	84%	87%
Corn starch	---	---	---	---	---	---	---	---
Deproteinized whey	87%	83%	87%	81%	85%	79%	79%	77%
DDGS	62%	75%	83%	82%	82%	71%	70%	75%
Developer base mix	100%	---	---	---	---	---	---	---
Dicalcium P, 18.5% P	---	---	---	---	---	---	---	---
DL-Methionine	---	---	---	100%	100%	---	---	---
Dried skim milk	93%	88%	97%	96%	89%	92%	97%	91%
Extruded/expelled soybean meal	89%	88%	88%	91%	84%	85%	87%	86%
Extruded soy protein concentrate	95%	95%	95%	94%	94%	94%	93%	94%
Grow-finish base mix	100%	---	---	---	---	---	---	---
Hard red winter wheat	81%	89%	89%	90%	90%	84%	90%	86%
High oil corn	78%	87%	92%	90%	86%	82%	84%	87%
Hominy feed	---	---	---	---	---	---	---	---
Lactose	---	---	---	---	---	---	---	---
Limestone	---	---	---	---	---	---	---	---
L-Threonine	---	---	---	---	---	100%	---	---
L-Tryptophan	---	---	---	---	---	---	100%	---
Lysine HCl	100%	---	---	---	---	---	---	---
Meat and bone meal	80%	82%	81%	83%	63%	80%	78%	79%
Methionine hydroxy analog	---	---	---	100%	100%	---	---	---
Milo	81%	87%	90%	89%	83%	84%	83%	87%
Monocalcium P, 21% P	---	---	---	---	---	---	---	---
Peas	88%	85%	86%	84%	79%	80%	82%	81%
Potassium chloride	---	---	---	---	---	---	---	---

Table 17, continued

Poultry meal	80%	81%	80%	77%	72%	77%	75%	74%
Pulverized oat groats	79%	83%	83%	86%	85%	80%	82%	81%
Restaurant grease	---	---	---	---	---	---	---	---
Salt	---	---	---	---	---	---	---	---
Select menhaden fish meal	95%	94%	94%	94%	88%	88%	90%	93%
Sow add pack	---	---	---	---	---	---	---	---
Sow base mix	---	---	---	---	---	---	---	---
Soy hulls	60%	68%	70%	66%	66%	61%	63%	61%
Soybean meal, 44% CP	89%	88%	88%	91%	84%	85%	87%	86%
Soybean meal, 46.5% CP	90%	89%	89%	91%	87%	87%	90%	88%
Soybean oil	---	---	---	---	---	---	---	---
Soybeans, full fat	86%	84%	86%	85%	80%	83%	82%	83%
Spray dried whey	87%	83%	87%	81%	85%	79%	79%	77%
Spray-dried blood cells	94%	88%	92%	96%	91%	94%	94%	91%
Spray-dried blood meal	94%	88%	92%	96%	91%	94%	94%	91%
Spray-dried animal plasma	94%	88%	92%	96%	91%	94%	94%	91%
Starter base	100%	---	---	100%	100%	100%	---	---
Trace mineral premix	---	---	---	---	---	---	---	---
Vitamin premix with phytase	---	---	---	---	---	---	---	---
Wheat bran	71%	76%	78%	79%	77%	70%	74%	75%
Wheat middlings	89%	92%	93%	93%	91%	88%	91%	90%

[a] Adapted from NRC (1998), 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.).

Table 18. True ileal digestibility values of amino acids in some feed ingredients commonly used in swine diets (as-fed basis)[a].

	True Digestible amino acids, %							
Ingredient	Lysine	Isoleucine	Leucine	Methionine	Cystine	Threonine	Tryptophan	Valine
Alfalfa meal, dehy	0.41	0.46	0.86	0.02	0.07	0.44	0.11	0.55
Bakery byproduct	---	---	---	---	---	---	---	---
Barley	0.28	0.31	0.58	0.15	0.17	0.28	0.10	0.40
Beef tallow	---	---	---	---	---	---	---	---
Calcium chloride	---	---	---	---	---	---	---	---
Canola meal	1.62	1.12	2.09	0.64	0.76	1.21	0.34	1.40
Choice white grease	---	---	---	---	---	---	---	---
Copper sulfate	---	---	---	---	---	---	---	---
Corn	0.20	0.24	0.91	0.15	0.16	0.24	0.05	0.34
Corn starch	---	---	---	---	---	---	---	---
Deproteinized whey	0.17	0.11	0.19	0.03	0.04	0.10	0.10	0.10
DDGS	0.49	0.76	2.64	0.45	0.45	0.75	0.15	1.01
Developer base mix	3.14	---	---	---	---	---	---	---
Dicalcium P, 18.5% P	---	---	---	---	---	---	---	---
DL-Methionine	---	---	---	99.00	---	---	---	---
Dried skim milk	2.66	1.65	3.56	0.88	0.27	1.49	0.49	2.12
Extruded-expelled soybean meal	2.69	1.90	3.22	0.61	0.62	1.57	0.57	1.95
Extruded soy protein concentrate	3.99	3.14	5.04	0.85	0.94	2.63	0.84	3.20
Grow-finish base mix	5.24	---	---	---	---	---	---	---
Hard red winter wheat	0.28	0.36	0.77	0.18	0.26	0.31	0.14	0.46
High oil corn	0.23	0.23	1.05	0.17	0.17	0.26	0.05	0.39
Hominy feed	---	---	---	---	---	---	---	---
Lactose	---	---	---	---	---	---	---	---
Limestone	---	---	---	---	---	---	---	---
L-Threonine	---	---	---	---	---	99.00	---	---
L-Tryptophan	---	---	---	---	---	---	98.50	---
Lysine HCl	78.60	---	---	---	---	---	---	---
Meat and bone meal	2.01	1.10	2.41	0.56	0.32	1.27	0.22	1.61
Methionine hydroxy analog	---	---	---	88.00	---	---	---	---
Milo	0.18	0.32	1.09	0.15	0.14	0.26	0.08	0.40
Monocalcium P, 21% P	---	---	---	---	---	---	---	---
Peas	1.32	0.73	1.30	0.18	0.24	0.62	0.16	0.79
Potassium chloride	---	---	---	---	---	---	---	---

Table 18, continued

Poultry meal	2.66	1.63	3.11	0.85	0.47	1.68	0.36	1.86
Pulverized oat groats	0.38	0.46	0.81	0.17	0.19	0.35	0.15	0.58
Restaurant grease	---	---	---	---	---	---	---	---
Salt	---	---	---	---	---	---	---	---
Select menhaden fish meal	4.57	2.42	4.27	1.66	0.50	2.32	0.59	2.82
Sow add pack	---	---	---	---	---	---	---	---
Sow base mix	---	---	---	---	---	---	---	---
Soy hulls	0.43	0.30	0.52	0.08	0.13	0.26	0.09	0.31
Soybean meal, 44% CP	2.52	1.75	3.01	0.56	0.59	1.47	0.53	1.77
Soybean meal, 46.5% CP	2.72	1.92	3.26	0.61	0.64	1.61	0.59	2.00
Soybean oil	---	---	---	---	---	---	---	---
Soybeans, full fat	1.91	1.35	2.37	0.45	0.44	1.17	0.39	1.39
Spray dried whey	0.78	0.51	0.94	0.14	0.21	0.57	0.14	0.46
Spray-dried blood cells	8.00	0.43	11.68	0.78	0.56	3.18	1.29	7.74
Spray-dried blood meal	7.00	0.91	9.95	0.95	0.95	3.55	1.39	6.40
Spray-dried animal plasma	6.43	2.38	7.00	0.72	2.39	4.44	1.28	4.50
Starter base mix	7.26	---	---	5.21	---	4.26	---	---
Trace mineral premix	---	---	---	---	---	---	---	---
Vitamin premix with phytase	---	---	---	---	---	---	---	---
Wheat bran	0.45	0.37	0.76	0.20	0.06	0.36	0.16	0.54
Wheat middlings	0.51	0.49	0.99	0.24	0.29	0.45	0.18	0.68

[a] Adapted from NRC (1998), 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.).

Notes

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