National Swine Nutrition Guide

Understanding the Nutrient Recommendations in the National Swine Nutrition Guide

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Introduction

Pigs require energy (from carbohydrates, lipids and protein), amino acids, minerals, vitamins and water for body maintenance, growth, pregnancy, and lactation. Each of these essential nutrients must be provided in adequate amounts and in forms that are palatable and efficiently utilized throughout the life-cycle of the pig in order for it to maximize genetic potential. Several factors affect the quantity of nutrients pigs need (see PIG Factsheet #07-01-07, Factors Affecting Swine Nutrient Recommendations) and different approaches exist to applying the principles of swine nutrition. Therefore, it is important for users of the National Swine Nutrition Guide (NSNG) to understand the approaches used in establishing and presenting nutrient recommendations in the Guide.

Objectives

- Provide the basis for the nutrient recommendations in the NSNG
- Define dietary energy and the common energy systems used in swine nutrition
- Define energy partitioning within the body
- Identify means to express amino acid recommendations
- Explain ideal protein or amino acid balance
- Describe means to express phosphorus recommendations and the importance of the calcium to phosphorus ratio
- Describe means to express trace mineral and vitamin recommendations
- Outline methods of expressing nutrient recommendations

Basis for nutrient recommendations

Nutrient recommendations in the NSNG are based on both the 1998 National Research Council (NRC) [1] and research published since 1998. Values published by the NRC do not include any safety margins. They are the committee's best estimates of minimum nutrient requirements for nutrients for pigs typically fed corn-soybean meal-based diets under experimental conditions that normally provide ideal growing conditions. In commercial production situations, a margin of safety is added to the published nutrient requirements; in the NSNG those levels are referred to as "recommendations". A margin of safety was applied to each nutrient in order to establish a recommendation for that nutrient in the NSNG. Margins of safety are necessary to account for any number of factors that affect nutrient needs (see PIG Factsheet #07-01-07, Factors Affecting Swine Nutrient Recommendations) and variability in nutrient composition and in nutrient bioavailability of feed ingredients (see PIG factsheet #07-07-09, Composition and Usage Rate of Feed Ingredients for Swine Diets). Nutrient cost and environmental issues surrounding nutrient excretion were also considered when determining safety margins.

Nutrient recommendations in the NSNG were established according to predetermined pig performance standards; for example, daily weight gain, feed intake, carcass lean gain, litter size and litter weaning weight. No particular genetics or line was considered. Those performance standards accompany the nutrient recommendations in the NSNG to provide transparency and to allow individuals to tailor recommendations to specific situations.

Energy

Energy is not a nutrient per se, but oxidation of carbohydrates (starch, sugar, and fiber), protein (amino acids), and lipids (fats and oils) by living cells produce energy. This energy can then be either released as heat from the animal or retained for use in powering the animal's metabolic processes. Energy is required by pigs for maintenance, growth (lean and fat), reproduction, lactation, physical activity, and thermoregulation [1]. Because pigs fed ad libitum will generally consume feed to meet their requirement for energy [1], it is important to have accurate estimations of the energy concentration of feed ingredients. Accurate estimation of energy concentration then allows for an estimation of daily feed intake and formulation of diets needed to meet the pig's requirements for amino acids, minerals, and vitamins based on dietary intake.

Energy Systems

Feed ingredients can have varying levels of energy concentration based upon the chemical composition of the feedstuff and how it is utilized by the animal. Dietary energy is provided by the carbohydrate, fat, and protein fractions of feed ingredients. Carbohydrates from cereal grains are the most abundant energy source in swine diets. Fat and oils contribute on average 2.25 times more gross energy than carbohydrates [1], but are included in diets in lower quantities. Also, protein contributes to the total energy in the diet. While carbohydrates from cereal grains contribute the greatest proportion of energy in swine diets, it is important to note that protein sources, such as soybean meal, also contribute energy to the diet. Furthermore, fiber sources, such as soybean hulls, contribute little "usable" energy to young pigs, but may contribute greatly to meeting the energy requirements of older swine due to increased fermentation in the hindgut as pigs age.

Energy concentration in feed ingredients is often expressed as kilocalories (kcal) or megacalories (Mcal) of gross energy (GE), digestible energy (DE), metabolizable energy (ME), or net energy (NE) [1]. The energy concentration of the diet is often expressed as kcal per unit of diet (kcal/kg, kcal/lb) and energy requirements are often listed as kcal or Mcal per day.

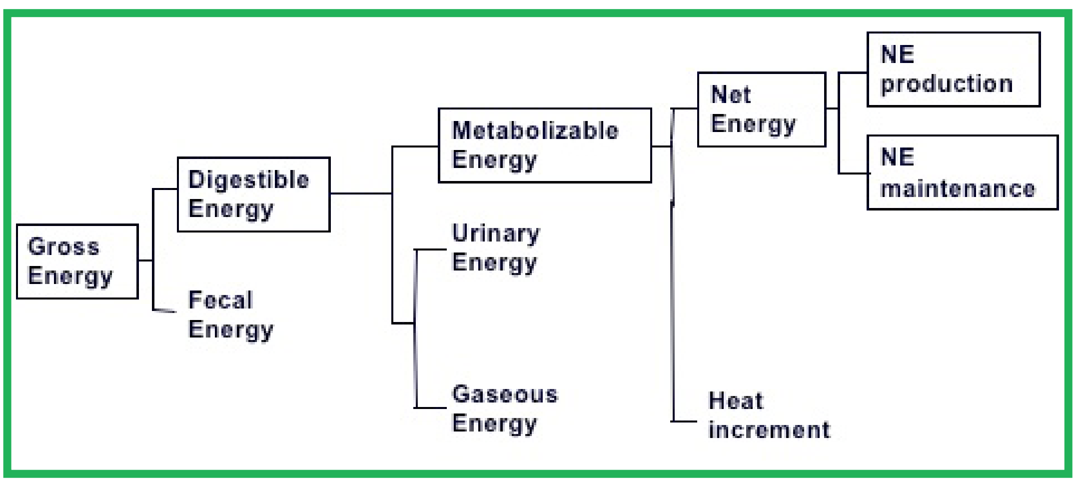

Figure 1. Partitioning of feed energy (gross energy) during digestion and metabolism. Adapted from [2].

Gross energy (GE) of a substance is the energy (heat) liberated when that substance is combusted (Figure 1). The proportions of carbohydrate, fat, and protein in a feedstuff determine the GE concentration. Digestible energy (DE) is dietary GE intake minus the GE in the excreted feces. Metabolizable energy (ME) is defined as DE minus the GE of urinary and gaseous losses. The energy released through gaseous losses is very small, and, thus, is often ignored [1]. Net energy (NE) is the difference between ME and heat increment. Heat increment is the heat produced from the digestion and metabolism of nutrients in an animal's diet and by fermentation in the intestinal tract. Normally, the heat increment is wasted energy, but it can be used to maintain body temperature in environments colder than the thermoneutral temperature of the animal [1]. Net energy is the energy that is retained by the animal for maintenance and productive purposes. Therefore, NE is considered to be the most accurate estimate of an animal's need for energy [2].

The energy system (GE, DE, ME, NE) used in diet formulation is often based on the availability of and confidence in the energy value for specific feed ingredients. The determination of the GE of a feedstuff is relatively simple. However, because the energy component of the diet is not 100% digestible, energy is lost via the feces. Therefore, GE is not an accurate method of determining the usable energy concentration of the diet. Digestible energy takes into account the energy lost in the feces. Because the difference between DE and GE concentration of feed ingredients can be quite large, DE is a more accurate estimate of the energy supplied in the diet. The DE concentration of a feedstuff is easily determined; thus, DE values for many feed ingredients are available. Due to the availability of DE concentration of many feed ingredients, use of the DE system is fairly common. However, one must realize that DE is not a "true" measure of the energy available to the pig for maintenance and productive purposes.

The ME concentration of feed ingredients is a better estimate of the usable energy concentration due to the fact that ME accounts for energy lost via urine and gases. Unlike the DE to GE ratio which can vary greatly depending on feedstuff, the ME to DE ratio is fairly consistent across a large number of feed ingredients.[1] The ME to DE ratio for common corn-soybean meal based diets is approximately 96% [3]. Much like DE, the ME concentration of many feed ingredients is widely available. The ME system is the most common and widely used energy system in the U.S.

Because the GE, DE, and ME systems all have shortcomings in estimating the usable energy of a feedstuff, the NE system offers the potential to more accurately predict the "true" energy concentration of a feedstuff or , in other words, the energy available to the pig for maintenance and productive purposes [2]. However, the determination of the NE concentration of feed ingredients is a very difficult and tedious process and varies depending on the physiological age of the animal. Thus, NE accurate values for feed ingredients for all stages of production are limited. However, as more NE values for feed ingredients become available and the confidence in these values increases, the pork industry will move toward the NE system. The advantages of using the NE system are expanded when feeding co-products, fat sources, and high protein feed ingredients. Also, use of the NE system may reduce feed costs per pig sold [3, 4].

The NE values for feed ingredients can vary greatly depending on the starch, fiber, protein, and fat concentration. For example, the ME concentrations of corn and soybean meal are similar (1,551 and 1,533 kcal/lb for corn and soybean meal, respectively; [1]). However, when comparing the NE concentrations, the NE concentration of soybean meal is lower than that for corn. Thus, the ME system overestimates the "true" energy concentration of soybean meal. The same is true for other feed ingredients containing relatively high protein and fiber concentrations. The DE or ME system will overestimate the "true" energy concentration of these feed ingredients, while underestimating the contribution of starch and fat sources.

Energy Recommendations for Swine

The daily energy recommendations for swine were estimated based on NRC [1] equations. For the growing pig, daily ME needs were based on maintenance energy needs plus the ME needed for protein and fat deposition. The ME requirement for the gestating sow is the sum of energy needed for maintenance, protein and fat accretion, and for the products of conception. Estimation of daily ME needs for the lactating sow is the sum of that needed for maintenance and milk production. Sow body weight change during lactation also affects the daily ME needs of the lactating sow.

Means of expressing amino acid recommendations

Pigs of all ages and stages of the life cycle require amino acids to enable them to grow and reproduce. Amino acids are the structural units of protein. During digestion, proteins are broken down into amino acids and peptides. The amino acids and peptides are absorbed into the body and are used to build new proteins, such as muscle. Thus, pigs require amino acids, not protein. Diets that are "balanced" with respect to amino acids contain a desirable level and ratio of the 10 essential amino acids (of the 20 amino acids) required by pigs for maintenance, growth, reproduction, and lactation. Those 10 essential amino acids for swine are: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. These amino acids must be provided in the diet at a minimum level in order to meet the pig's requirement for the development of body protein [1].

Only a certain proportion of each of the amino acids in a feedstuff is digested and absorbed by pigs. When amino acids are expressed on a total amino acid basis then it refers to the absolute amount present in the diet and does not take into account the digestibility of those amino acids present [5, 6, 7]. Therefore, terminology to describe the bioavailability and ileal digestibility of amino acids in pig feed can be put into three categories. Those categories are apparent, standardized, and true digestible. Apparent ileal digestibility (AID) of amino acids is defined as the net disappearance of ingested dietary amino acids from the digestive tract proximal to the distal ileum. The true ileal digestibility (TID) reflects the proportion of the dietary amino acids that disappears from the digestive tract proximal to the distal ileum corrected for measured endogenous losses. Standardized ileal digestibility (SID) is derived by correcting AID values for a constant defined basal endogenous losses of amino acids [8]. Amino acid recommendations in the NSNG are presented as SID and total for lysine.

Ideal protein or amino acid balance

Amino acids are required in a precise proportion or ratio for each body protein. The concept of an ideal protein or ideal amino acid balance is to provide a perfect pattern of essential and nonessential amino acids without any excesses or deficiencies. This pattern is supposed to reflect the exact amino acid requirements of the pig for maintenance and growth. Therefore, an ideal protein provides exactly 100% of the recommended level of each amino acid. Proteins in milk and eggs come closest being considered idea for pigs.

Standard diets are usually formulated to meet the pig's requirement for lysine (the most limiting amino acid). Excesses of many other amino acids exist even when combinations of supplemental protein sources and crystalline amino acids are used. Amino acid excesses in practical swine diets do not hinder pig performance [5, 6, 7, 9, 10].

Requirements of the remaining amino acids are expressed as a ratio to the first limiting amino acid in the diet (lysine). The amino acid ratios established for each phase of production are shown in Table 1 for the nursery phase, Table 2 for grower and finisher phases and Tables 3 and 4 for the breeding herd. Once the SID lysine recommendations were established for the NSNG, those for the remaining essential amino acids were derived from the ratios in Tables 1 to 4.

Table 1. Amino acid ratio recommendations for nursery pigs[a]

Type of diet	**Phase 1 to 4**
Body weight, lb	**9 to 45**
Standardized ileal digestible	--------------------------% of lysine -------------------------
Lysine	100
Threonine	62
Methionine	28
Methionine + cysteine	58
Tryptophan	17
Isoleucine	55
Valine	65
Arginine	42
Histidine	32
Leucine	100
Phenylalanine + tyrosine	94
Phenylalanine	60

[a]Derived from the 1998 National Research Council (NRC) [1] and research published since 1998.

Table 2. Amino acid ratio recommendations for growing and finishing swine[a]							
Type of diet	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 5 + RAC[b]**	**Phase 6 + RAC[b]**
Body weight, lb	**45 to 90**	**90 to 135**	**135 to 180**	**180 to 225**	**225 to 270**	**225 to 270**	**270 to 315**
Standardized ileal digestible	---------------% of lysine---------------						
Lysine	100	100	100	100	100	100	100
Threonine	63	63	64	65	67	67	68
Methionine	29	29	29	29	30	30	31
Methionine + cysteine	58	58	60	60	62	62	63
Tryptophan	16	16	16	16	16	16	16
Isoleucine	55	55	55	55	55	55	55
Valine	65	65	65	65	65	65	65
Arginine	40	38	36	34	34	34	34
Histidine	32	32	32	32	32	32	32
Leucine	100	100	100	100	100	100	100
Phenylalanine + tyrosine	94	94	94	94	95	95	96
Phenylalanine	60	60	60	60	60	60	60

[a]Derived from the 1998 National Research Council (NRC) [1] and research published since 1998.
[b]Ractopamine hydrochloride (Paylean®).

Table 3. Amino acid ratio recommendations for gestating females and breeding boars[a]		
	Gestating females	**Breeding boars**
Standardized ileal digestible	---------------% of lysine---------------	
Lysine	100	100
Threonine	76	74
Methionine	27	27
Methionine + cysteine	70	70
Tryptophan	18	18
Isoleucine	57	57
Valine	68	68
Arginine	89	89
Histidine	30	30
Leucine	94	94
Phenylalanine + tyrosine	100	100
Phenylalanine	58	58

[a]Derived from the 1998 National Research Council (NRC) [1] and research published since 1998.

Table 4. Amino acid ratio recommendations for lactating females[a]				
	Parity 1		Parity 2 or greater	
	Litter weaning weight, lb		Litter weaning weight, lb	
	145	115	160	125
Standardized ileal digestible	----------% of lysine----------			
Lysine	100	100	100	100
Threonine	59	63	62	66
Methionine	25	27	26	28
Methionine + cysteine	46	49	48	51
Tryptophan	18	19	18	20
Isoleucine	54	57	57	59
Valine	82	86	85	89
Arginine	53	53	57	59
Histidine	38	40	40	42
Leucine	110	114	114	121
Phenylalanine + tyrosine	96	101	101	108
Phenylalanine	53	55	55	59

[a]Derived from the 1998 National Research Council (NRC) [1] and research published since 1998.

Means of expressing phosphorus recommendations

Phosphorus is required in the diet of pigs for proper skeletal growth and mineralization, as well as cellular functions. In the pig, approximately 75% of the phosphorus in the body is in the skeleton while 25% is in the soft tissues. Phosphorus is found in every cell in the body serving in the energy system (ATP), cell structural components like phospholipids, phosphorylation sites for enzyme activation, and an initiation factor for protein synthesis[11]. The amount of phosphorus required for growth is less than the amount required for maximum bone development[1].

In swine nutrition, phosphorus can be expressed in three different ways: total, bio-available, or digestible phosphorus. Total dietary phosphorus is the chemically analyzed amount of phosphorus in the diet, but does not provide any indication of the amount of phosphorus that is available to the pig for maintenance and growth. Many of the feedstuffs used in swine diets are of plant origin and the phosphorus in these ingredients is poorly digested by the pig. This is because the majority of the phosphorus (60-90%) is bond to a phytic acid ring called phytate [12]. Pigs do not have the digestive enzyme, phytase, to remove the phosphorus from this structure and make it available to the animal. Commercial phytase is available for use in swine diets and is discussed in more detail in PIG Factsheet # 07-03-04 (Feed Additives for Swine – Enzymes and Phytase).

This effect of phytic phosphorus is best demonstrated by looking at corn and soybean meal which have only 28 and 32% of the total phosphorus being digestible by the pig; the rest is bound to the phytic ring and is unavailable to the pig (PIG factsheet #07-07-09, Composition and Usage Rate of Feed Ingredients for Swine Diets). This is why total phosphorus should not be the only value to consider when evaluating whether the pig's phosphorus requirement is met.

Digestible phosphorus is the value frequently utilized for diet formulation in the European pork industry. Digestible phosphorus is determined similar to other nutrients through a collection of feces or ileal digesta when a specific ingredient is fed. This allows the determination of the digestible phosphorus of a specific feed ingredient by difference and refines diet formulation to feeding closer to the pig's phosphorus requirement. Most swine nutritionists in the United States use relative bio-available phosphorus values for feed ingredients and requirement estimates [13]. Relative bio-available phosphorus often is determined based on a relative relationship to building bone ash or bone strength compared to an inorganic standard that was fed in that experiment. Most relative bio-available phosphorus studies use monocalcium phosphate, dicalcium phosphate, or monosodium phosphate as the reference standard to which the feed ingredient relative bio-availablity is compared to. One challenge with the relative bio-available phosphorus system is that the phosphorus reference standard is assumed to be 100% available, but in reality these standards have between 76 and 92% digestible phosphorus in the pig (PIG factsheet #07-07-09, Composition and Usage Rate of Feed Ingredients for Swine Diets). Variability in the digestibility of the standards used to compare feed ingredients to for relative bio-availability means the actual bio-available phosphorus values can have considerable variation.

The NSNG provides recommendations for both relative bio-available phosphorus and digestible phosphorus as concentration in the diet and related to dietary energy content. We recognize that most of the U.S. pork industry uses the bio-available phosphorus system [13], but we are providing digestible phosphorus recommendations in an effort to guide the industry toward use of more accurate and reliable nutrient recommendations for phosphorus. Additionally, we utilized lean accretion rates of grow-finish pigs to estimate our recommendations for digestible phosphorus, We believe this approach provides further refinement of our digestible phosphorus recommendations for the growing-finishing pig, because it is more reflective of its true requirement.

The total phosphorus recommendations presented in the NSNG should be used as a guideline only; those recommendations may not be obtained when formulating practical diets on an available or digestible basis. Also, the total phosphorus recommendations in the NSNG will not be achieved when phytase is included in the diet.

The calcium to phosphorus ratio is important in swine nutrition. A wide calcium to phosphorus ratio will decrease the absorption of phosphorus, especially when phosphorus is fed near the requirement level [1]. A narrower calcium to phosphorus ratio will result in more efficient phosphorus absorption and is more critical in the young pig [1]. The suggested calcium to total phosphorus ratios in the NSNG is 1-1.2:1 across production phases. In general, the recommended calcium to bio-available phosphorus ratio is 1.4-2.4:1 and the ratio is from 1.6-3.0:1 for calcium to digestible phosphorus, both increasing as the pig matures from the nursery period to grow-finish and sow production phases.

Phytase inclusion in swine diets will reduce total dietary phosphorus by approximately 0.05 to 0.10 percentage units, depending on the amount of enzyme added. This will increase the calcium to total phosphorus ratio to about 1.5:1, which is near the upper recommended limit for this ratio. However, the ratio of calcium to available phosphorus or digestible phosphorus will remain unchanged as the diets will still be formulated to the same available or digestible phosphorus; it will just now require less total phosphorus to meet the pig's needs.

Means of expressing trace mineral and vitamin recommendations

Recommendations for trace minerals and vitamins can be expressed either as total dietary concentrations or supplemental additions to the diet. Recommendations that are expressed on the basis of total dietary concentrations rely on grains, by-products and protein supplements in swine diets to provide trace minerals and vitamins that pigs require. While such ingredients contain critical vitamins and trace minerals, the amount provided is often not sufficient. The concern with vitamins is that those in grains, by-products, and protein sources are lost during storage, drying, and processing or may be unavailable to the pig. Therefore, to reduce the risk of deficiencies that might occur due to differences in ingredient quality and to ensure optimum and reliable pig performance, we recommend that certain trace minerals and vitamins be routinely added to the diet. Therefore, trace mineral and vitamin recommendations in the NSNG represent additions to the diet. Consequently, diets formulated according to NSNG recommendations will usually contain a higher total concentration of many trace minerals and vitamins than the actual quantities added to the feed as the trace mineral and vitamin contributions of the various feed ingredients are included in complete feed formulations.

Methods of expressing nutrient recommendations

Nutrient recommendations for pigs are expressed either as percent of the diet, on a ratio relative to dietary energy content or amount per day. Table 5 shows an example using these methods of expressing the SID lysine recommendation for gestating swine. In order for a parity 1 female producing 12.5 pigs/litter and consuming 4.7 lb of a diet containing 1.5 Mcal of ME/lb to meet her SID lysine need during gestation, she should consume a diet containing 0.60% SID lysine or 1.82g of SID lysine per Mcal of ME. In addition, her daily SID lysine need is 12.8 g/day.

Table 5. Example of methods of expressing lysine recommendations (as-fed basis)[a]		
	Parity 0 and 1	
Assumed litter size, total born	**10.5**	**12.5**
Assumed daily feed intake, lb	**4.6**	**4.7**
Dietary metabolizable energy, Mcal/lb	**1.5**	**1.5**
Standardized ileal digestible		
Lysine, % of diet	0.58	0.60
Lysine, g/Mcal ME[b]	1.76	1.82
Lysine, g/d	12.2	12.8

[a]Refers to gestating females; parity 0 = first gestation period (female has not farrowed a litter); parity 1 = second gestation period (female has farrowed one litter previously).
[b]Recommended amount relative to dietary metabolizable energy (ME) density; energy values of ingredients from PIG factsheet #07-07-09 (Composition and Usage Rate of Feed Ingredients for Swine Diets) were used in the calculations.

When expressing nutrient recommendations on a percentage of the diet basis, dietary energy density or feed intake must be considered. Otherwise, it is likely that the animal's nutrient needs will not be met as intended. Expressing nutrient recommendations relative to dietary energy ensures nutrient density is altered in accordance to changes in dietary energy density, for example when fat is added to the diet. Amino acid, calcium and phosphorus recommendations in the NSNG are expressed both as percentage of the total content of the diet and amount relative to dietary energy content.

Summary

Pigs require energy, amino acids, minerals, vitamins and water for body maintenance, growth, pregnancy and lactation. Each of these essential nutrients must be provided in adequate amounts and in forms that are palatable and efficiently utilized throughout the life-cycle of the pig in order for it to perform according to it genetic potential. As the science becomes more refined, we can more accurately determine the true digestibility and availability of nutrients to the animal. This knowledge allows nutritionists to more adequately meet the nutrient needs of the pig. The result is less nutrient waste and error in diet formulation, thus reducing costs and the environmental impact of pork production.

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Frequently asked questions

Which energy system is most commonly used in the United States?
The most common energy system used in the United States is the ME system. The DE system also may be used. In the future, the NE system will be used more commonly.

What are the advantages of the net energy system?
The NE system more accurately predicts the energy available to the pig for maintenance and productive purposes. Also, using the NE system can reduce feed costs due to the fact this system more accurately predicts the energy available to the pig from the dietary ingredients.

For which ingredients does the net energy system predict energy concentration of feed ingredients better than the metabolizable energy system?
The NE system will provide a more accurate estimate of the true energy concentration of high-protein and high-fiber feed ingredients. The ME system will tend to overestimate the "true" energy concentration of high-protein and high-fiber feed ingredients.

Should I move to the net energy system?
The decision to move to the NE system should be based on the understanding of the system and the confidence in the NE concentration of feed ingredients. Before a complete move to the NE system, diets should be formulated on a ME basis with NE also calculated. By doing so, producers can become familiar with the NE concentration of the diet at a specific ME concentration. Once familiarity and confidence with the NE concentration of the diet are established, then a complete move to the NE system becomes easier. Producers should work with their nutritionist when attempting to move to the NE system.

Do excesses of amino acids in the diet impair pig performance and does a reduction or elimination of the excesses improve pig performance?
There is little evidence to indicate that the performance of pigs fed diets containing a more ideal balance of amino acids is better or worse than that of pigs fed practical corn or milo with soybean meal based diets. However, if excess amino acids are reduced, nitrogen excreted through the urine and feces will be reduced, meaning that less nitrogen is in the manure.This will reduce the amount of land required to properly manage the nitrogen in the manure. Unless there is a strong incentive to reduce nitrogen in the manure, choose sources of amino acids that will produce the lowest cost gain.

Is there really a difference between bio-available phosphorus and digestible phosphorus values?
Yes. Digestible phosphorus is determined similar to other nutrients through a collection of feces or ileal digesta when a specific ingredient is fed. Relative bio-available phosphorus is determined based on a relative relationship to building bone ash or bone strength compared to some inorganic standard that was fed in that experiment. Most relative bio-available phosphorus studies use monocalcium phosphate, dicalcium phosphate, or monosodium phosphate as the reference standard that the feed ingredient relative bioavailablity is compared to. The phosphorus standard is assumed to be 100% available, but in reality these standards have between 76 and 92% digestible phosphorus in the pig. So the variability in the digestibility of the standards the feed ingredients have been compared to for relative bioavailability means the actual values can have considerable variation. Most of the United States uses the relative bio-available phosphorus values for feed ingredients and requirement estimates; however, digestible phosphorus provides a more accurate estimate for swine diet formulation.

How does total dietary phosphorus concentration change when phytase is added to the diet?
When phytase is added to swine diets the amount of dietary total phosphorus is reduced due to improved bio-availability of phosphorus. As the level of total phosphorus decreases, the total calcium to total phosphorus ratio must be monitored as so that the ratio does not exceed 1.5:1. If the total Ca:P becomes over 1.5:1, performance will begin to be reduced.