Swine Nutrition

By **H.H. STEIN***

PIGS do not require specific feed ingredients, but they do have daily requirements for energy and specific nutrients. The National Research Council (NRC) provides estimates of nutrient requirements for all phases of pig production (updated in 2012). These estimates do not contain safety factors to allow for variations in pig requirements, variations in the level or availability of nutrients in feed ingredients or a loss of vitamin potency during processing and storage.

It is also recognized that, under certain circumstances, nutrient requirements may be greater than those recommended by NRC. That may be the case if high-fiber diets are fed to pigs, because the requirement for digestible threonine increases as a consequence of feeding high-fiber diets, or if pigs are under chronic disease pressure, which may elevate the requirement of certain nutrients.

It is, therefore, not unusual to include some nutrients, especially vitamins and micro-minerals, at concentrations greater than the requirement estimates published by NRC (2012).

Nutrient, energy requirements of pigs

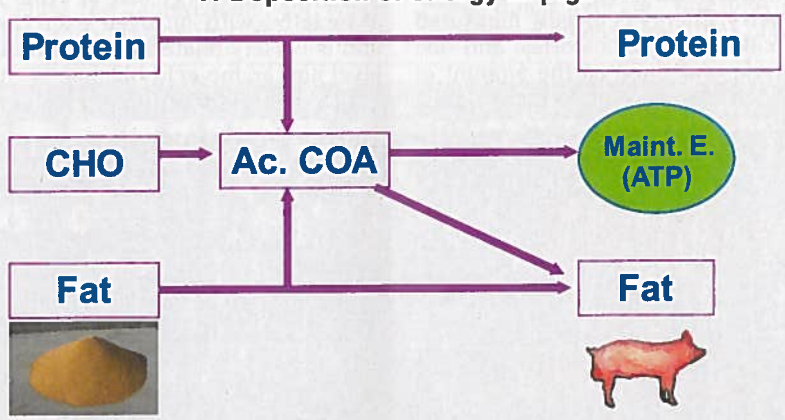
Diets fed to pigs usually contain five of the six classes of nutrients, i.e., carbohydrates, lipids, minerals, protein, water and vitamins. Water is usually provided on an *ad libitum* basis from water nipples to all categories of pigs, but the remaining five classes of nutrients are included in the dry portion of the diet.

Pigs have specific needs for amino acids (from the protein fraction), fatty acids (from the lipids), vitamins and minerals. In contrast, pigs do not have specific needs for carbohydrates, but it is common to feed relatively large quantities of carbohydrates to pigs in the form of starch and fiber. Pigs also have requirements for energy, and diets are usually formulated to contain a specific concentration of digestible or metabolizable energy.

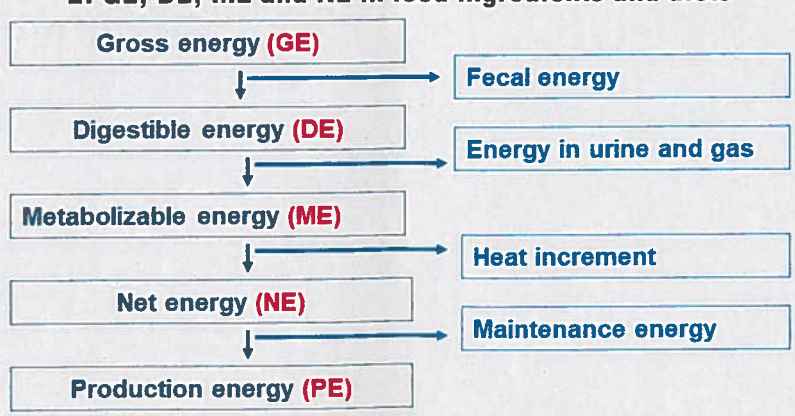
Diets may also contain non-nutritive feed additives such as acidifiers, probiotics, exogenous enzymes and others. The use of antibiotic growth promoters was once common in diets for weanling and growing/finishing pigs, but the recent change in the labeling of most of these antibiotics has greatly reduced the use of antibiotic growth promoters in diets for pigs. In contrast, the use of acidifiers, enzymes and probiotics have increased, and most pig diets now contain one or more non-antibiotic feed additive. Whereas some of these additives are considered "alternatives" to antibiotic growth promoters, they typically have different modes of actions and different impacts on overall pig growth performance.

Energy. Energy is needed for all productive functions in the body. Energy in feed ingredients and diets is supplied by protein, fat, and carbohydrates. The pig will use the majority of dietary protein to synthesize body protein that will be deposited in muscles and other tissues. If there are more protein in the diet than needed to maximize protein synthesis, the excess amino acids will be deaminated, the nitrogen will be excreted in the urine and the remaining part of the amino acids will be utilized for energy in the form of ATP or stored as fat. Dietary fat may also be directly stored in the adipose tissue of pigs and in other tissues — or fat may be oxidized and used to synthesize ATP that the pig needs for maintenance energy. The carbohydrates in the diets are primarily used for ATP synthesis and any excess carbohydrates that are not needed for ATP synthesis will be used to synthesize fat that will be deposited in the body. A small portion of the carbohydrates may also be stored as glycogen in the liver or skeletal muscles, but quantitatively, this is a minor amount of energy and almost all excess energy is stored as fat. The concentration of energy is greater in lipids than in carbohydrates and amino acids, and including high concentrations of lipids in

1. Deposition of energy in pigs



2. GE, DE, ME and NE in feed ingredients and diets



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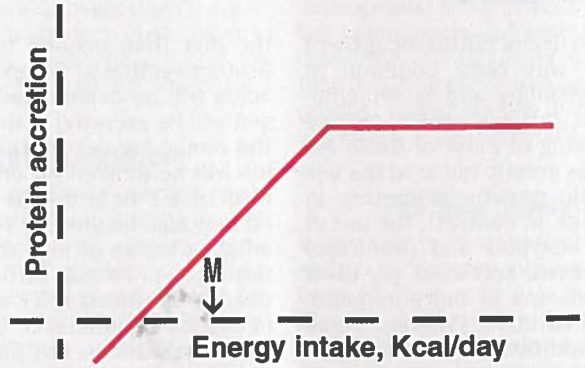
3. Protein accretion versus digestible energy intake



the diets, therefore, often results in the formulation of high-energy diets (Figure 1).

An energy system expresses the energy requirements of the body and the energy supplied by feeds in the same units. The energy systems commonly used in swine nutrition are digestible energy (DE), metabolizable energy (ME) and net energy (NE). Each of these systems has advantages and disadvantages (Figure 2).

The total amount of energy in feedstuffs is gross energy (GE), which is measured using bomb calorimetry. Energy is usually measured as calories or kilocalories, and one calorie is defined as the amount of heat that is required to increase the temperature of 1 g of water from 16.5°C to 17.5°C. Some of the energy-containing nutrients are not digested and absorbed from the digestive tract, but instead are excreted in the feces, and the amount of fecal energy varies among feed ingredients. Subtraction of fecal energy from GE results in the calculation of DE. However, some energy is also excreted in urine, and some is lost as methane gas from the digestive tract. The amount of energy that is lost in methane is small and is usually ignored. Energy lost in urine is associated with nitrogen excretion and is closely related to the protein level and amino acid balance of the entire diet. Subtraction of urine energy losses from DE results in calculation of ME, and ME values of feed ingredients are routinely determined and used in diet formulation. Many energy systems around the world are based on the DE or ME of feed ingredients, and diets are often formulated using this system.

As pigs consume and metabolize nutrients from their diets, they generate heat, which is lost, and therefore, cannot be used for production. The heat that is lost is greater from fiber than from lipids, starch and amino acids, and different diets may, therefore, result in different amounts of heat losses. By subtracting the energy lost in heat from ME, the NE of diets and feed ingredients is sometimes calculated, and some energy systems are based on the NE of ingredients rather than DE or ME. Theoretically, NE systems will predict the energy in diets better than DE or ME systems. However, whereas DE and ME values can be determined in routine metabolism studies in diets and ingredients, NE values are substantially more difficult and expensive to generate and rely on a number of assumptions about nutrient absorption that may not always be accurate under all circumstances. Use of NE systems has, therefore, not been universally adopted, but there is a growing interest around the world in using the NE system. It is, therefore, likely the

NE system will be implemented in more countries in the future as requirements for greater precision in diet formulation results in a need for increased accuracy in predicting energy values of diets and feed ingredients.

Amino acids. The amino acid supply from the diet is determined largely by the amino acid composition of the diet and the digestibility of the protein in which the amino acids are bound. Protein digestibility varies enough among feedstuffs that it is important to formulate diets on the basis of digestible rather than total amino acids. Amino acid digestibility is most correctly determined at the end of the small intestine (the ileum) because the microbes in the hindgut degrade and/or synthesize amino acids. In addition, because amino acids cannot be absorbed from the hindgut, amino acids synthesized or digested in the hindgut are not available for protein synthesis in the pig. However, to avoid the influence of hindgut microbes on the estimated values for digestible amino acids, values for "ileal digestibility" need to be determined. These values are obtained after surgically installing a cannula in the distal small intestine of the pig and collecting intestinal fluids over several days, which allows the apparent ileal digestibility of individual amino acids to be calculated.

Measures of apparent digestibility always show low values for a few key amino acids (threonine, tryptophan and cysteine) because they are in high concentrations in endogenous proteins. As a result, values for apparent ileal digestibility for amino acids in individual feed ingredients are not always additive in mixed diets, and it is, therefore, not always possible to predict the concentration of apparent digestible amino acids in mixed diets based on values obtained in individual ingredients. However, if values for apparent ileal digestibility of amino acids are corrected for basal endogenous losses — determined using a protein-free diet — values for standardized ileal digestibility of amino acids are calculated, and these values are additive in mixed diets. As a consequence, diets for pigs should always be formulated based on values for standardized ileal digestibility.

The pig requires an adequate dietary supply of each of the 10 indispensable amino acids. Independently estimating requirements for each of these 10 amino acids under varying conditions is a daunting task. A more practical approach involves determining the requirements for lysine and then calculating the requirements of the other amino acids using the concept of "ideal protein." This concept relies on the assumption that amino acid requirements for a specific group of pigs are constant and, therefore, can be calculated from the requirement for lysine. As a consequence, only the requirement for lysine is determined empirically, whereas the requirements for all other amino acids are calculated. However, if high-fiber diets are fed or if pigs are under chronic immune challenges, the requirement for certain amino acids may increase, and the assumptions for ideal protein may not be completely correct. Results of recent research has also highlighted the negative effects of excess leucine in diets for pigs. Excess leucine can sometimes not be avoided if large quantities of corn protein or sorghum protein is used in the diets, which will be the case in diets based on dried distillers grains with solubles (DDGS) or corn gluten meal. In those cases, the concentration of dietary leucine may be close to twice as high as the requirement and this will result in reduced feed intake and reduced protein synthesis. These negative effects of excess dietary leucine may be overcome by addition of extra valine, isoleucine and tryptophan, which indicates that pigs fed diets based on high quantities of pro-

absorbed lysine is used for protein accretion is assumed to decline as the pig grows, such that the amount of lysine needed to support 100 g of protein accretion is 10.4 g in a 20-kg pig and 12.5 g in a 120-kg pig. Adjustments for the greater efficiency of pigs with faster protein accretion is incorporated into the model.

Using the requirement for lysine to calculate the requirement for all other indispensable amino acids is an accepted and widespread practice that has proved to result in satisfactory pig growth performance. The requirement for digestible lysine is relatively well characterized for most genotypes of pigs, which is a prerequisite for using this approach. However, all processed feed ingredients to which heat has been applied may have been heat damaged, and the amino acid with greatest risk of heat damage is lysine. Heat damage results in a reduction in the concentration as well as the digestibility of lysine, and because of heat damage, there is greater variability in the concentration and digestibility of lysine than for any other amino acid among different batches of the same feed ingredient. To be certain that pigs receive the intended levels of digestible lysine, it is, therefore, necessary to have quality control measures in place to make sure each batch of each feed ingredient is not heat damaged. Because of the reduction in lysine concentration in heat damaged feed ingredients, and because crude protein is not changed by heat damage, calculation of the lysine to crude protein ratio will provide an indication about whether or not a feed ingredient is heat damaged. The lysine-to-crude protein ratio in feed ingredients that have not been heat damaged has been determined for some of the most commonly used feed ingredients fed to pigs (Table). If the ratio between lysine and crude protein is less than the values indicated in the Table, the ingredient is most likely heat damaged. If a heat-damaged ingredient is received, supplemental crystalline lysine will be needed to maintain satisfactory animal growth performance.

Phase feeding. Amino acid requirements expressed as a percent of the diet decline during the feeding period for growing-finishing pigs, so feeding appropriate diets throughout the growing finishing phase requires several diets. Feeding too few diets may cause overfeeding of amino acids during some periods of the growing phase, with detrimental effects on both cost and the nitrogen content of manure. The most satisfactory method for managing those changes is to provide a predetermined amount of each feed (a feed budget). Feeding gilts and barrows separately, if practical, also provides an opportunity to optimize amino acid provisions, because gilts have a greater requirement for amino acids — measured as a percentage of the diet — than barrows.

Nutritional programs: Gestating sows

Amino acids. The amino acid requirements of gestating sows are relatively low because most of the energy is used for maintenance, and the amino acid requirements for maintenance are low relative to the energy requirement. However, younger sows are still growing and need amino acids for body protein deposition and older sows may have lost body protein during lactation, which needs to be replenished. As for growing pigs, the requirements for amino acids in gestating sows is a combination of requirements for maintenance and protein deposition.

Energy. Gestating sows differ from pigs in most other stages of production in needing a feed intake restriction. That creates challenges in the physical management of feed delivery to ensure that each animal consumes the target amount of feed. Sows that consume too little during gestation enter the lactation phase in a condition with limited body stores of fat and protein. Sows that consume too much during gestation usually eat too little during lactation, when adequate energy intake is most critical because high feed intake in lactation is needed to maximize milk production.

The fact that the energy requirement of gestating sows is less than their voluntary intake allows for the use of fibrous ingredients in the diet without reducing performance, and it is also believed that dietary fiber contributes to increased satiety of sows. It is, therefore, common to add at least one high-fiber ingredient in diets for gestating sows.

Historically, sows were kept on a low plane of nutrition early in gestation and the provision of feed was increased during the last 3-4 weeks of gestation to account for the increased nutrient demand of the fetuses during this period. However, it has been demonstrated that by feeding approximately 2.5 times the energy requirement during early gestation, pig litter size is increased. In contrast, there appears to be no benefits of increasing feed allowance during late gestation and sows may be fed the same amount of feed during the late gestation as in the middle of gestation.

Nutritional programs: Lactating sows

High intake needed. Modern sows can produce impressive quantities of milk, and it requires large amounts of energy, amino acids and other nutrients to support that milk production. That is why it is important that sows consume enough feed to supply those nutrients. Inadequate nutrient intake can reduce milk production and/or cause mobilization of excessive amounts of maternal body tissue. Intake of feed below the requirement may also create metabolic/endocrine conditions that reduce the quality of the developing ovarian follicles that will produce the next litter of piglets.

It is both important and difficult for lactating sows to achieve adequate feed intake. However, feed intake can be encouraged through proper management. Heat stress should be minimized by taking appropriate environmental management steps, such as drip-cooling. The feeding process should be managed to encourage a high level of feed intake. Adequate provision of water is critical to encourage maximum feed intake and milk production. Use of ad libitum feeders will also increase feed intake of sows.

Fat. Supplementing lactation diets with fat is unlikely to improve subsequent reproduction in most cases, but it almost always increases litter weaning weights and may be recommended for that reason. This is an effect of dietary fat resulting in increased milk fat concentrations and, therefore, increased energy intake of the nursing piglets.

Amino acids. The amino acid requirements of lactating sows can be estimated by a factorial approach, as described for finishing pigs; the model is available from NRC (2012). The factors to be considered are maintenance, requirements of the mammary gland for milk production and the amino acids contributed by mobilization of maternal tissue. Again, the requirements for amino acids other than lysine are estimated using ratios.

Summary

The science and practice of swine nutrition are old but very active and increasingly sophisticated. This article provides an overview of salient aspects of swine nutrition, with some expansion in especially critical or rapidly changing areas. ■