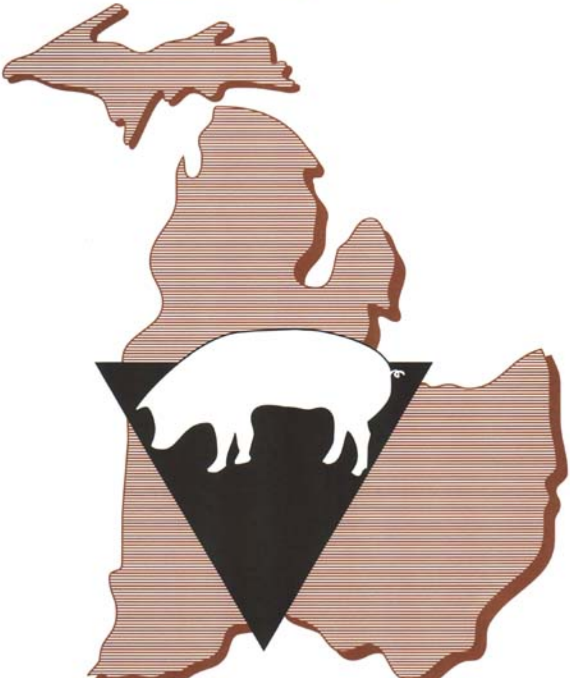
Bulletin 869

Tri-State



Swine Nutrition Guide

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The Ohio State University Extension
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Contents

Figures

Tables

Tri-State Swine Nutrition Guide

Foreword

Successful pork production requires the linking of numerous disciplines that affect conception, growth, and composition of swine. Effective management attempts to control as many of these influencing factors as possible. Nutrition is an extremely important factor having obvious impact on biological expression, performance, and economic success. This Nutrition Guide was produced to not only provide recommendations for nutrient levels, sources, balances, and interactions to optimize performance throughout the life cycle of swine but also to explain why the recommendations were made.

Nutrients provided to swine need to be targeted to specific needs, reflecting the environment and genetic capability of different groups of swine. Genetics has undergone its most radical changes in the swine industry during this last decade. Nutrition must likewise be altered to meet the changing dietary needs commensurate with the more efficient, meatier swine of today. Industry changes often occur faster than the supporting research. Therefore, research needs to be both applied and basic to understand the mode of action, to make the appropriate dietary recommendations, and then to effectively communicate that information.

Similarly, dietary allowances need modification in response to the vastly different environment provided for most swine. Facilities continue to be improved to meet the comfort and well-being of swine. Physical stresses have been reduced. High herd-health, reflecting the environment, is a readily understood management factor of modern pork production. Additionally, diets need modification to reduce the level of nutrients in the manure without affecting performance. Excess levels of nitrogen and minerals can lead to contamination of surface and ground water and cause excessive odors.

This Tri-State Swine Nutrition Guide was developed to most accurately meet the needs and production methods in the geography offered by the states of Indiana, Michigan, and Ohio. Swine nutritionists from the three land-grant universities, working in conjunction with nutritionists from support industries and with swine producers, have developed recommendations based on an extremely large database of research conducted worldwide but fine-tuned to the climate, ingredients, and production methods of these three states. The strengths of the three Departments of Animal Sciences are clearly demonstrated in the document. The Guide provides current, accurate information for feeding pigs throughout their life cycle while being cognizant of the effects of feeding programs on manure generation and aroma. Formulations have begun to reflect nutrient choices and levels that will minimize swine waste and odor.

We administrators congratulate the authors of this Guide for their leadership and research review which is so fundamental to the creation of this fine document.

To those who read, evaluate, and utilize the recommendations herein, we anticipate improved performance and satisfaction for your efforts.

Departmental Administration of the Three Animal Science Departments When This Publication Was Written

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Introduction

This publication is intended to estimate the nutrient requirements of swine by considering the regional conditions within the tri-state area of Indiana, Michigan, and Ohio. In the discussion section of each production phase, we reviewed the various physiological, genetic, and environmental factors that can affect the pig's nutrient requirements. References are cited only when graphs or tabular information were directly used, but we did not cite the voluminous number of scientific reports used to establish our nutritional recommendations. Also included is a listing of feeds that are commonly available in this region, their compositions and nutrient availabilities when appropriate, and the effect that processing has on their feeding value. Factors that can affect the composition of the diet are identified in Figure 1. After evaluating the pig's nutritional requirements and why the requirements change between each production phase, we focused on answering frequently asked questions by considering different management practices, types of facilities, genetics, production stages, and feed ingredients. The swine nutritionists at each of the three universities (Michigan State University, The Ohio State University, and Purdue University) met several times to prepare this publication and then consulted with several industry and Extension specialists in the tri-state area for their critique.

Major Factors Influencing Nutrient Recommendations and Pig Performance

Although numerous factors affect the pig's nutrient requirements, it is the integration of these factors that makes a swine-feeding program successful. Not only must recommendations include an understanding of the pig's nutritional needs at the different production phases, but these recommendations must also provide an understanding of what nutrients are needed and how they affect pig growth and reproduction. How to evaluate different feedstuffs that should be used in formulating diets to achieve maximum economic return for the swine enterprise is an important part of determining a successful swine-feeding program.

Other factors besides nutrition can limit the performance responses of swine and affect feed costs. Although each factor can influence the pig's nutritional requirements (Figure 2), these factors each have the capability of influencing the other. Because these factors can vary greatly between swine operations, a university or a feed-industry specialist may be needed to make adjustments in the herd's nutritional program if a specific problem exists.

The major factors having the greatest influence on the pig's nutritional requirements in the tri-state area are environment, facilities, health, genotype, and management.

Environment

At each stage of production, the physical environment (temperature, humidity, and air movements) can have a profound influence on pig performance responses. There is a range of temperatures at which the pig is comfortable **(comfort zone),** where weight gain and feed utilization are optimum. This comfort zone has a range of temperatures bracketed by a lower critical temperature **(LCT)** and an upper critical temperature **(UCT).** The environmental requirements within the comfort zone differ for each stage of the life cycle. The temperature range within the comfort zone can be influenced by several factors such as the type of housing and bedding conditions. Beyond the ranges of the comfort zone, the pig will modify its behavioral and physiological responses, which could lower its weight gain and feed-intake responses. The effects of environmental conditions, within the comfort zone and beyond the ranges of LCT and UCT, on different swine performance responses are presented in Figure 3.

Not only can the physical environment influence pig performance, but the pig's social environment (pen space, feeder holes per pig, group size, etc.) can also affect its performance response. For example, when pigs are housed in facilities with limited access to feeder space, or when the number of pigs per pen are over- or underpopulated, performance responses and cost of gain are affected.

Facilities

There is a wide range in the types of facilities that are used today during each production phase. Housing conditions can clearly influence the pig's performance response, but they will also affect the pig's nutrient needs. For example, pigs that are housed in complete confinement normally have a higher growth rate and feed intake than pigs housed on pasture or drylot. Environmental conditions and facilities can therefore independently and jointly influence the pig's nutritional requirements. Management of a facility that results in a facility environment low in gases, odors, dust, and waste material will help to maintain pig health and result in optimum growth and reproductive performance responses. Such an environment will also be more healthy for the herdspersons working in that facility.

Health

Perhaps no factor can influence the cost of gain and animal performance more than the presence of subclinical swine diseases. Evaluating the health status of a herd or a group of purchased pigs will require the expertise of a veterinarian. Subsequent herd-health care and its supervision by a veterinarian specializing in swine can be an invaluable service. Subclinical health conditions ultimately will influence the pig's nutrient requirements, feed intake, and cost of gain. A successful preventative herd-health program in coordination with a veterinarian can be an important investment for the swine producer.

Genotype

During the genetic selection process of the past few decades, changes have occurred in the way some genotypes have responded to the environment and to other conditions. For example, some genetic lines have responded better to complete confinement but poorly to outdoor conditions. Some sows perform more favorably to early weaning but perform poorly to later weaning. One trait that has changed and also seems to vary between genetic lines is the pig's feed intake response. Some of the leaner genotypes have demonstrated a lower feed consumption and a lower daily gain than other genetic crosses. Because of potential genetic differences for muscle deposition between genotypes, the efficiency of feed utilization is also quite different. Those genotypes with a higher potential for lean tissue growth, but which may also have a lower feed intake, must have their diets formulated differently than pigs of other genetic and appetite characteristics. Consequently, seedstock producers, particularly those producing synthetic lines, should provide the commercial swine producer with expected feed intakes, performance responses, carcass information, sow longevity, and other herd characteristics. Attempts to evaluate nutrient requirements for specific genotypes is difficult without this information.

Management

Management will directly influence the decisions of how the various factors will be used and how they will affect the swine enterprise. Individuals who apply modern technology to swine production are the key in making the swine enterprise profitable. For example, the feeding program for pigs in the all-in, all-out production system, the proper timing of artificial insemination, and the timing for changing diets in the split-sex or the phase-feeding programs are decisions made by the herdsperson that can affect performance and production costs. Under optimum environment, facilities, health, and nutritional conditions, the daily and long-term management decisions made by swine personnel will greatly affect the pig's response to different feeding programs.

Figure 1. Various Factors of Feed Grains That Affect Feed Formulation.

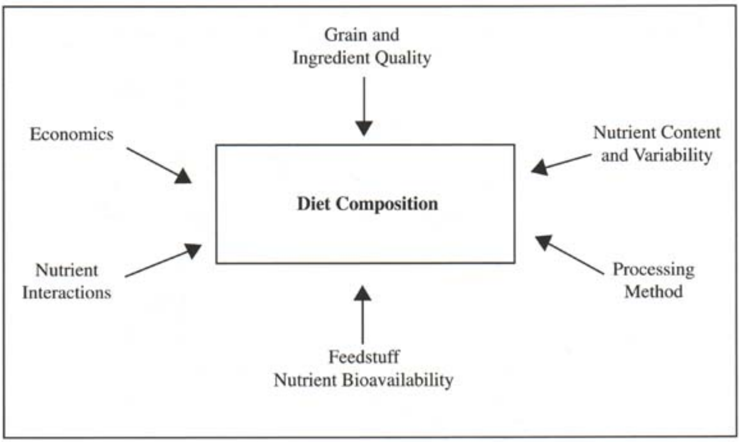


Figure 2. Factors That Can Affect the Nutritional Requirements of Swine.

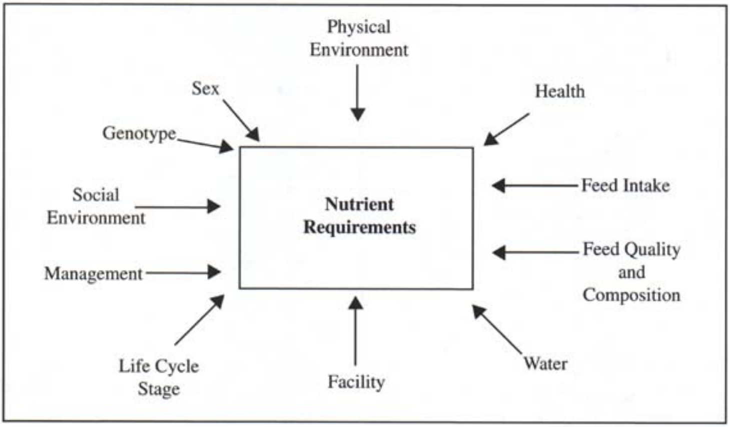
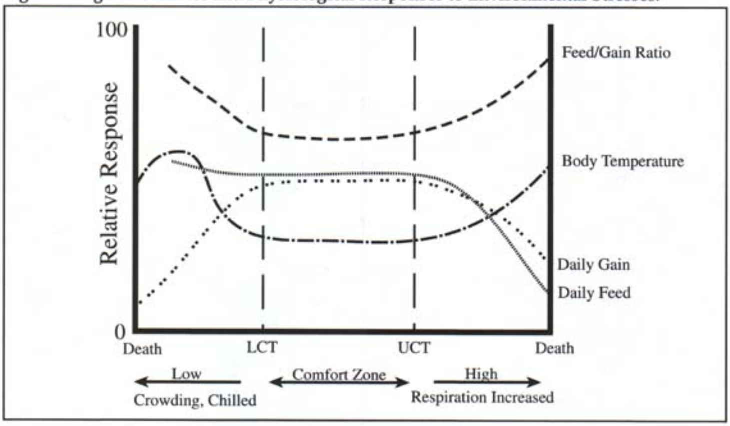


Figure 3. Pig Performance and Physiological Responses to Environmental Stresses.



Note: 1. Leaner pigs may have a narrower temperature range within the comfort zone because of the lower subcutaneous fat covering.

2. The actual temperature at the LCT (lower critical temperature) and UTC (upper critical temperature) will be influenced by housing conditions.

Nutrient and Nutrient Utilization

The quantity of each nutrient required for the body's function is largely influenced by the genotype, sex, and production phase of the pig. Although many nutrients perform similar functions and are often grouped together, nutrients within a group generally cannot substitute for each other. The major groups are: **energy** (carbohydrates, fats), **proteins** (amino acids), **minerals** (macro- and microminerals), **vitamins** (fat soluble and water soluble), and **water**.

Energy

Energy is technically not a nutrient but is released by the metabolism of carbohydrates (starch) and fats (lipids) from the dietary components. In the United States, energy is expressed in kilocalories (kcal) or megacalories (Mcal). One megacalorie is equivalent to 1,000 kcal. Energy losses occur during the body's digestive and metabolic processes, with only part of the total energy from the feed available for body maintenance and productive functions **(Net Energy)**.

The energy content of feedstuffs is normally expressed as either **digestible** or **metabolizable** energy. The digestible energy (DE) content of a feedstuff is determined by subtracting the amount of energy in the feed from the energy lost in the feces. Metabolizable energy (ME) is the digestible energy minus the energy lost in urine and gases (Figure 4). The energy lost as gas (in the gastrointestinal tract) is usually negligible (less than 1% of total energy intake). The National Research Council (NRC) is currently using the digestible energy (DE) value to formulate swine diets. Most feedstuffs can be converted to the ME value by multiplying DE by 0.96.

Net energy is therefore used by the pig for maintenance (NEm) and for productive purposes (NEp) such as growth, development of products of conception, milk production, etc. As the pig approaches market weight, an increasing amount of energy is used for maintenance, which contributes to a poorer feed efficiency. In addition, there is an increasing amount of fat deposited in the carcass. The amount of energy needed for body fat gain is higher than that for muscle gain and is the major reason for the higher feed conversion of finisher pigs. For example, to deposit 1 lb. of muscle (0.20 lb. of protein plus 0.80 lb. of water) approximately 0.95 Mcal of energy is required. On the other hand, 1 lb. of body fat (0.83 lb. of lipid plus 0.17 lb. of water) requires approximately 4.84 Mcal of energy or approximately five times the energy cost of lean-tissue gain.

Energy must be provided in large amounts over that needed for maintenance to achieve optimum growth and reproduction responses. The major source of dietary energy for the growing pig is from the **carbohydrate** (i.e., starch) component of grains or their by-products. Feedstuffs such as corn, sorghum, and wheat contain high percentages of starch (>60%). Cereal grains such as barley also contain starch as their predominant energy source, but they also contain higher levels of the complex carbohydrates (e.g., fiber) that have a low digestibility.

Fats provide the most concentrated source of dietary energy to the body. Dietary fat provides 2.25 times more energy on a weight basis than does carbohydrate. The percent fat (oil) in most cereal grains is substantially less than the carbohydrate component and generally ranges from 1 to 4%. Dietary fats also contain the essential fatty acids that are used for the synthesis of various hormones. The presence of fat in the intestinal tract is essential for the absorption of fat-soluble vitamins.

Dietary fat and fiber can be used effectively to either reduce or increase body-heat production, respectively. When the environmental temperature is below the pig's comfort zone (LCT), the pig has a higher energy requirement, and if adequate energy is not provided in the feed, the pig must divert body fat toward the production of heat for body maintenance. In contrast, when environmental temperatures exceed the upper limit of the comfort zone (UCT), the pig's respiration rate increases, the pig consumes less feed, and a greater proportion of the consumed dietary energy is used for maintenance. Both of these conditions will increase the pig's feed conversion (Figure 3).

Dietary fat releases less heat when it is digested and metabolized, and thus will impose less heat stress on the animal when environmental temperatures are high. In contrast, dietary fiber releases more heat when digested and metabolized, thus providing a source of heat for the body when environmental temperatures are low. Because the lower heat increment from dietary fat produces less heat, the inclusion of fat in swine diets during the summer months can result in improved weight gains and feed conversion responses. Conversely, when environmental conditions are colder and additional body heat is needed, the use of fiber in the diets of swine may be beneficial. Consequently, the use of fats and fiber in swine diets during the appropriate season may be determined by production stage, economics, and environmental temperatures.

Other aspects of the diet can affect energy utilization and subsequent feed conversion (e.g., amino acids, fatty acids, and fiber). Diets that contain excess amino acids or improper balances of amino acids are utilized less efficiently than diets that contain amino acids in the correct balance. This is because the pig must use energy to get rid of excess dietary protein (amino acids), resulting in a lowered feed conversion. Dietary fiber is the complex carbohydrate found in grain, hulls, and plant forage material and is not efficiently digested by swine. Because of its lower digestibility, the dietary fiber component of the diet reduces the usable dietary energy content, which also results in a poorer feed conversion. Fiber is, however, often used in formulating diets for barrows where it reduces the amount of fat deposited. Fiber is also often incorporated into sow gestation diets where energy restriction is desired, or it is used under conditions to relieve animal constipation problems.

Protein and Amino Acids

The crude protein content of a diet has been the term historically used as an indicator that indirectly reflects the pig's requirement for amino acids. The term "crude" is used because feedstuffs not only contain amino acids (each amino acid contains nitrogen), but grains and other feeds also contain non-amino acid nitrogen. When the crude protein content of a grain is determined, it is the total nitrogen that is analytically determined, whereupon it is then calculated mathematically to a protein equivalent value, thus the term "crude protein." The nonprotein portion of the diet (e.g., urea, nitrates, etc.) is not effectively used by the pig but its nitrogen is analytically determined along with the nitrogen in the proteins.

Pigs in fact do not specifically need protein, but rather require amino acids for the formation of muscle and other body proteins. Ten of the 20 amino acids required are considered as dietary essentials because the pig is not able to synthesize them at all or at a rate that will adequately meet the pig's needs. Therefore, there are 10 essential amino acids (Table 1) that must be provided in the diet at a minimum level in order to meet the pig's requirement for the development of the body proteins.

Amino acids are also required in a precise proportion or ratio for each body protein. Because the development of the different body proteins occurs at differing rates, the amino acid requirements are constantly changing.

The balance of dietary amino acids can affect their overall utilization. Expressing the dietary requirements for the 10 essential amino acids on the basis of an ideal amino-acid balance **(ideal protein)** is based on the principle that the amino-acid composition of the diet resembles the amino-acid composition of developing pig tissue with an additional amount needed for maintenance. An ideal protein mixture in the diet thus contains the optimum balance of all amino acids required for the maintenance, growth, and/or reproduction functions of the pig. The ratios of the different amino acids are, however, usually expressed in relation to the dietary lysine requirement. Although we currently use "total" amino-acid concentration, the use of "digestible" or "available" values will be more widely used in the near future, as they more accurately reflect what is absorbed and/or utilized from the various feed sources.

Lysine is generally the first-limiting amino acid (i.e., the first amino acid to be deficient) in a cereal grain-soybean meal mixture. Therefore, we usually formulate swine diets to a specific lysine, rather than protein, level. This results in the other amino acids being in excess. There is no scientific information that indicates that slight excesses of amino acids in corn-soybean meal diets are detrimental to the performance of pigs. Rather, excess amino acids are metabolized in the pig to urea, the end-product of nitrogen metabolism, and it is subsequently excreted in the urine. Practical methods to provide a more ideal amino acid balance include the use of various protein source combinations and/or "synthetic" amino acid additions. Supplementing a low-protein diet with amino acids such as lysine•HCl (78.8% lysine) is oftentimes more cost effective than using an additional amount of a particular protein source. It also has the advantage of reducing nitrogen excretion in the manure. Other than synthetic lysine or methionine, it is generally not economical to consider adding other synthetic amino acids to swine diets because they generally are too expensive.

Lowered protein quality may occur during the processing of grain or animal products, especially when excessive heat is used. This heat modifies the chemical structure of the protein which may reduce the digestibility and bioavailability of certain amino acids to the animal.

Although protein or amino acids, when fed in excess of the pig's need, can be a source of energy, the use of protein as an energy source is not recommended because of the higher cost and higher nitrogen excretion in the animal's waste products.

Minerals

The **macro minerals** required by pigs are presented in Table 1 and are usually expressed as a percentage. Although these minerals are indigenous in the various feed grains, some are at low concentrations. Consequently, it is essential that the diet be balanced using supplemental mineral sources. Calcium, phosphorus, and magnesium are involved in bone development, but they also serve in many metabolic functions. Sodium, potassium, and chloride are involved in nutrient transfer across cell membranes, body pH regulation, water balance, and digestion. Sulfur is a component of several organic compounds in the body. Generally, magnesium, potassium, and sulfur do not need to be added to swine diets.

Other minerals are referred to as **trace or micro minerals** because they are required in the diet at very low concentrations (Table 1). These minerals are generally expressed in parts per million (ppm) with 1 ppm being equivalent to 0.0001% of the diet. These minerals are often involved in the structure of enzymes or body hormones and/or involved in activating metabolic enzymes. Although these trace minerals are present in grains and by-products, iron, zinc, copper, selenium, and iodine need to be supplemented. Nickel, silicon, vanadium, and arsenic have not been shown to be dietary essentials for the pig, but they are found in the body. The role of chromium as a dietary essential is currently unclear. Some research has shown that added chromium as chromium picolinate enhances muscle formation and improves reproductive performance, whereas other research has not confirmed these observations. It is possible that the chromium in many feed grains may be adequate to meet most of the metabolic functions of the element.

Mineral bioavailability is important, particularly for the trace mineral sources. Bioavailability not only includes its absorption but also its transport into the cell to perform a biological function. Several factors can influence mineral bioavailability:

- The chemical form of the mineral.
- The amount provided in the diet.
- The amount stored in the body.
- The health, age, and physiological state of the animal.
- The concentration of other minerals in the diet.

Recently, several organic forms of minerals have become commercially available. These minerals are most frequently bound to a protein or amino acid and are referred to as "proteinates" or "chelates" and often times are referred to as "organic minerals." These mineral sources have a relatively high bioavailability, but they are generally more expensive than the inorganic forms. Their value as part of the pig's diet will depend on the specific mineral. The major mineral sources used today and their relative bioavailabilities are listed in Table 2.

Vitamins

The **fat soluble vitamins** identified in Table 1 are needed for body tissue growth, maintenance, and reproduction. Therefore, the body requires a specified amount per day of each of these vitamins. Vitamins classified as **water soluble** are also identified in Table 1. These vitamins are generally used for metabolic purposes with the amount needed being proportional to the amount of feed or energy consumed. Feed components and intestinal microbial synthesis provide some of the B vitamins needed by the pig, but others must be added to the diet.

Storage, processing, and the contact of vitamins with certain trace minerals may lower the activity of many vitamins in the premixes, and mixed complete feeds. Some of the vitamins within the premixes are in a stabilized form that extends their shelf life. Premixes should always be stored in a cool, dry location and for a short time period. Purchasing a combination vitamin-mineral premix will result in more loss of vitamin activity than if the vitamin and mineral premixes were stored separately. Generally, a storage period not to exceed three months will be satisfactory for most vitamin premixes.

Water

Water is the largest single component of the pig's body (up to 90% of the baby pig). Quantitatively, it is required by the pig in amounts larger than any other nutrient. Water functions as a critical component of the pig's body, is essential for metabolism, and is the primary factor in body temperature control. Pigs usually consume 2 to 3 lbs. of water for every pound of feed consumed. If water is not readily accessible to the pig, if the pig is overcrowded, or if an adequate number of waterers are unavailable per pig, feed intake and subsequent daily gains will be reduced.

Table 1. Nutrients Needed by the Pig.

Essential Amino Acids	Essential Fatty Acids	Minerals		Vitamins	
		Macro	Micro	Fat Soluble	Water Soluble
Arginine	Linoleic	Calcium	Iron	Vitamin A	Thiamine
Histidine	Linolenic	Phosphorus	Zinc	Vitamin D	Riboflavin
Isoleucine		Magnesium	Copper	Vitamin E	Niacin
Leucine		Sodium	Selenium	Vitamin K	Pyridoxine (B_6)
Lysine		Potassium	Iodine		Biotin
Methionine		Chloride	Manganese		Vitamin B_{12}
Phenylalanine		Sulfur	Molybdenum		Folic acid
Threonine					Pantothenic Acid
Tryptophan					Choline
Valine					Vitamin C[a]

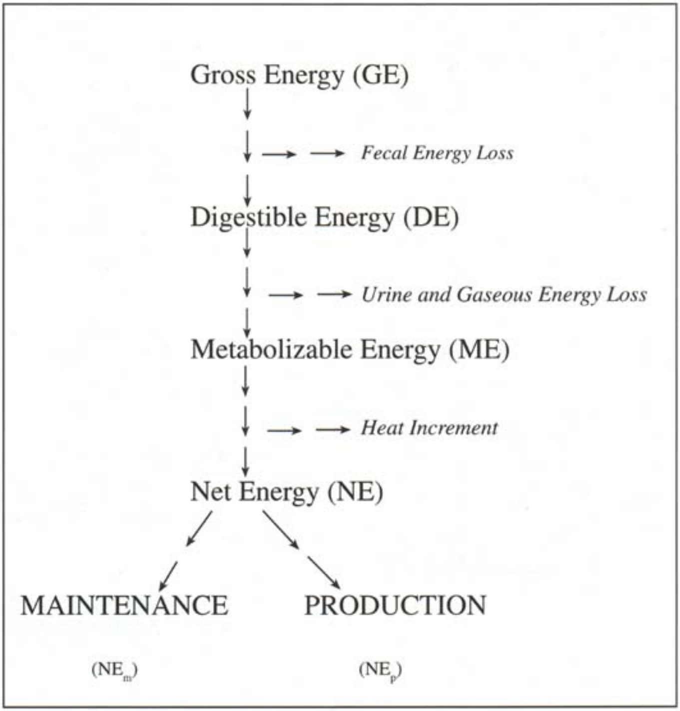
[a] Although vitamin C can be synthesized by the pig, research evidence suggests that the early-weaned pig may require a supplemental source in the diet for a short period postweaning.

Table 2. Commonly Used Forms of Minerals in Swine Diets.

Mineral	Form	Bioavailability	Nutrient Content[a]
calcium	bone meal	excellent	24
	carbonate	excellent	38
	mono- or dicalcium phosphate	excellent	18-21
	dolomitic limestone	good	22
copper	sulfate	excellent	25
	oxide	poor	79
	lysine[b]	excellent	10
iron	ferric oxide	unacceptable	—
	ferrous carbonate	poor	32
	ferrous sulfate	excellent	32
	iron methionine[b]	excellent	14.5
magnesium	sulfate	excellent	10
	oxide	good	54
	carbonate	excellent	30
manganese	sulfate	excellent	25
	methionine[b]	excellent	16
phosphorus	bone meal	excellent	12
	dicalcium phosphate	excellent	18.5
	monocalcium phosphate	excellent	21
	soft rock phosphate	poor	17
	defluorinate rock phosphate	excellent	20
selenium	sodium selenite	excellent	45.6[c]
	sodium selenate	excellent	41.8[c]
zinc	lysine[b]	excellent	10
	methionine[b]	excellent	18
	oxide	medium	72
	sulfate	excellent	36
	carbonate	excellent	78

[a] The concentrations may differ due to different water of hydration molecules attached to the element.
[b] The mineral proteinates or chelates may differ in their compositions due to different chemical bonding structures. See the manufacturer's composition of the different products that are available.
[c] Generally premixed to provide 0.3 ppm in the final diet mixture.

Figure 4. Energy Partition in Pig Nutrition.



Questions and Answers for the Nutrient Utilization Section

Q. Other than lysine, do I need to consider adding any other amino acids?

For most cereal grain-soybean meal-based diet mixtures, lysine is usually the first limiting amino acid for pig growth. Although the dietary lysine concentration is a good measure of the overall amino acid adequacy of the diet, other amino acids potentially low are isoleucine, valine, tryptophan, threonine, and methionine. The inadequacy of these latter amino acids can occur when other protein or amino-acid sources are used to replace soybean meal. For example, when plasma protein is used in pig starter diets, the diet is frequently inadequate in methionine.

Q. How important is the calorie:protein (lysine) ratio?

Pigs generally consume the amount of feed that satisfies their energy requirement. Consequently, as the dietary concentration of fat increases, the amount of feed consumed declines. When a lower quantity of feed is consumed such as when fat is added to the diet, it is essential that the energy (calorie):protein (lysine) ratio be maintained. Consequently, as feed intake declines, other dietary nutrients must be adjusted to a higher concentration.

Q. How important is the dietary calcium:phophorus ratio?

The ratio of dietary calcium to phosphorus is important for the optimal absorption and utilization of both minerals. When the diet contains a marginal level of phosphorus, a high calcium:phosphorus ratio will result in a lowered phosphorus absorption. A poor calcium:phosphorous ratio can reduce growth rate and bone calcification. A suggested calcium:phosphorus ratio for grain-soybean meal diets ranges between 1.2:1 to 1.5:1.

Q. How important is water quality?

Concerns about water quality are most commonly related to its microbial contamination. Microbial levels higher than 50 colony-forming units per liter are potentially harmful and require corrective action. Microbial levels less than 10 colony-forming units per liter are acceptable.

Q. Where do we get water analyzed?

Your State Board of Health will analyze water for bacterial contamination and nitrates.

Q. What minerals are in the water supply, and what effect do they have on pig performance?

The minerals most commonly found in ground water are iron, sulfate, chloride, and magnesium. These minerals can form chemical complexes with calcium, magnesium, and sodium, and are termed total dissolved solids. Concentrations of total dissolved solids above 5,000 ppm have been reported to cause diarrhea, poor performance, and poor locomotor function in pigs.

Q. Does high iron- or high sulfur-containing water harm pigs?

High iron will clog filters, screens, etc., of water lines. Water with high sulfur content has resulted in increased water consumption but has not been shown to affect pig performance. Extremely high iron and sulfate concentrations have, however, been suspected of causing diarrhea in young pigs.

Q. What other compounds in water are potentially harmful to pigs?

Nitrates are often present in ground and surface water. Nitrates can be converted to nitrites, which are harmful. The conversion to nitrite is necessary for toxicity to occur. Nitrites at levels less than 100 ppm are generally safe, but higher levels convert hemoglobin to methemoglobin. Methemoglobin does not carry an adequate amount of oxygen to the tissues and can result in animal death if an excess level is in the blood.

Q. What is the desired water flow rate in the different pig production phases?

In general, water must be accessible and be available in an ample quantity. Suggested water flow rates from nipple drinkers are:

Production Phase	Flow Rate
Starter pigs (10 – 50 lb.)	250 to 500 ml/minute (0.5 quart/minute)
Grower pigs (50 – 140 lb.)	500 to 750 ml/minute (0.75 quart/minute)
Finisher pigs (140 – 250 lb.)	750 to 1,000 ml/minute (1.00 quart/minute)
Sows and boars	1,500 ml/minute (1.50 quart/minute)

Pig Growth and Development

The pig is a fast-growing animal with the potential of achieving more than a hundredfold increase in body weight before 12 months of age. For pigs to achieve this rapid weight increase, large quantities of nutrients are needed for tissue development. The rate of development of the major body components is changing continually, at least until the pig attains its mature size.

Figure 5 demonstrates the relative rates of formation of the major body components (bone, muscle, fat) from birth (3 to 4 lb.) to 300 pounds body weight. Body tissues with the highest rate of formation in younger pigs are bone and muscle. Finisher pigs continue to deposit muscle and bone, but their rate of deposition declines, whereas body fat increases rapidly as body weight increases. Because pigs differ genetically in the rate and the development of these three major body components, the dietary nutrient requirements will reflect these changing body-development patterns.

Figure 5 also compares the body-tissue development of two differing genotypes. The "industry average" and the "lean" genotypes are depicted, but other genotypes with different development patterns are also present in the swine industry. There is generally a greater difference in body composition between genotypes during the finisher than during the grower period.

Skeletal Formation

Bone development is more rapid in younger animals but declines as the animal reaches market weight. Because of this, a higher dietary concentration of calcium and phosphorus is required for starter and grower than for finisher pigs. Although the rate of bone formation declines as the animal enters the latter stages of growth, the skeleton is still growing albeit at a slower rate. During the latter growth period, bones widen and become thicker and thus stronger. Finisher pigs therefore have the capacity to deposit calcium and phosphorus in their bone tissue beyond that needed to attain optimum growth responses.

The need for the higher deposition of minerals in bone is not necessary for pigs destined for market, whereas gilts that are being retained for the breeding herd need to store additional minerals which can serve as reserves for later reproduction. Consequently, replacement gilts fed a finisher diet containing lower calcium and phosphorus concentrations will likely develop a weaker skeletal structure. Increasing the dietary calcium and phosphorus by 0.10% above that recommended for market swine will result in optimum bone mineralization in replacement animals.

Body Proteins and Muscle

Each body tissue contains various proteins, and each of these proteins has a precise sequence of amino acids. Tissues also develop at different rates from birth to maturity. For example, the internal organs (i.e., liver, intestinal tract, and others) grow faster in younger pigs but more slowly in mature pigs. In contrast, other tissues (e.g., reproductive organs) develop more rapidly during the latter stages of growth. Because each tissue has a different amino-acid composition, the dietary amino-acid requirements will differ as these different tissues develop.

Muscle tissue develops at an increasing rate from birth until the mid to latter portion of the grower-finisher period, whereupon its rate of development declines. The period when muscle accretion declines largely depends upon the animal's genetic capability to deposit muscle. The potential number of muscle cells present at maturity is largely established genetically at conception, with their number completed by the time of birth. The leaner genotypes have a larger number of muscle cells at birth than those pigs that are not as lean. Muscle cells increase in size postnatally, but only in response to adequate nutrition and hormonal stimulation. Geneticists and seedstock companies have developed several improved lines, each having a specific rate of muscle development. The feeding of high-protein diets will not result in an increased muscle mass beyond the animal's genetic capability, but the feeding of a low-protein diet will clearly restrict its development and therefore its genetic potential. Consequently, it is possible to make a genetically lean pig fatter by feeding a low-protein diet, but impossible to make a genetically fatter pig leaner by feeding a high-protein diet. It is not possible to exceed the animal's genetic capability to produce muscle by nutritional means, but it is possible to restrict its genetic potential by poor nutrition.

The rate of muscle formation declines during the finisher period, but the timing and rate of this decline varies by the genetic makeup of the animal. There is currently a wide variation among genotypes, but most leaner genotypes have an increasing amount of muscle tissue to 160 to 180 lbs. before the rate of muscle development declines. In contrast, pigs with less muscle mass generally have a muscle deposition pattern that begins to decline at a lighter body weight (120 to 140 lbs.). Consequently, finisher pigs that have higher rates of muscle accretion will have a higher dietary amino-acid requirement than those genotypes with lower rates of muscle growth. Pigs of a lower muscle capability will therefore become progressively fatter as body weight is increased beyond 230–250 lbs.

Fat Development

Fat is an essential component of all body cells and is an essential component of cell membranes. Fat cells are formed early in the development process but do not fill until excess energy is fed to the pig. Their initial formation is largely under genetic influence, but the filling of these cells is influenced by nutrition. When the pig consumes an excess amount of carbohydrates or fats, it is deposited as fat, largely in the fat cells, whereas other nutrients, when fed in excess, are largely excreted. Fat in the subcutaneous (backfat) area serves largely as the storage area for energy, but it also serves as a natural insulation layer for the animal. The pattern of subcutaneous fat development occurs in a defined sequence, from the shoulder to the mid portion of the back, and from the rear toward the mid portion of the body. Although the area from the 10^{th} to the last rib has a lower backfat thickness than the rest of the topline, its depth at this site is highly correlated with total body fat. This value is subsequently used to evaluate and calculate lean gain and/or body condition.

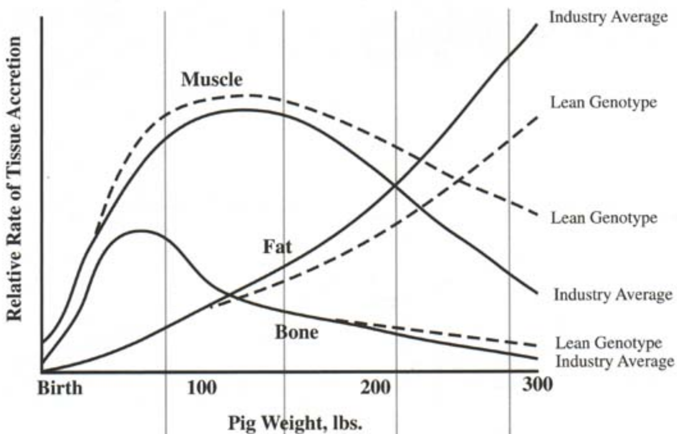
The amount of body fat deposited is influenced by nutrition and genetics, but the type of fat deposited is influenced by the type and amount of fat fed. Although fat deposition occurs throughout the life of the pig, its rate of deposition accelerates most rapidly during the latter part of the finisher period. This generally coincides with the period when muscle formation declines (Figure 5). The quantity of fat deposited increases faster and earlier in fatter genotypes, whereas the leaner genotypes have a lower deposition of fat at lighter body weights. Because meat packers are currently slaughtering pigs at heavier body weights (250 to 280 lb.), they desire pigs with less fat at heavier body weights. Heavier-weight pigs with a greater genetic potential for muscle development and a lower rate of fat accretion will therefore have less total fat at 250 to 280 pounds body weight.

Nutrition - Genetic Relationship

Pigs of differing genetic development potentials for the three major body components (bone, muscle, fat) have different nutrient requirements. Nutritional requirements for the leaner genotypes require more amino acids for muscle tissue deposition, but the formation of lean tissue also requires additional vitamins and minerals. As pigs mature and as the rate of their body components changes, the diet fed should reflect the pigs' changing requirements for nutrients. For example, younger grower pigs have a high rate of bone growth and therefore have a higher calcium and phosphorus requirement. The requirement for these minerals declines as the pig matures, because the rate of bone formation declines. If an accurate quantitative estimate of the three body component tissues could be determined during each stage of growth for each genetic line, we would be able to more accurately formulate diets that would more closely meet the pig's nutritional requirements. Computer modeling systems using information about the pig's changing composition and accurate information about the "available" nutrients in the diet will be used in the future for diet formulations.

Frequent changing of the pig's diet (phase feeding) will more clearly meet the specific nutrient requirements at the various stages of body development. Phase feeding reduces the oversupply of nutrients provided compared to situations where diets are changed less frequently. Dietary formulations, however, should be matched to the genetic potential of the pig. As specific information becomes available about the rate of bone, muscle, and fat formation for different genetic lines, and as pigs become more uniform within their feeding group, frequent diet changes (phase feeding) can be successfully implemented.

Figure 5. Relative Rates of Body Development and Nutrients Needed at Various Production Phases.



DIETARY NUTRIENT REQUIREMENTS

Minerals:	High	Medium	Medium	Med-Low
Amino Acids:	High	High	Medium	Medium
Vitamins:	High	High	Medium	Med-Low
Energy:	High	High	High	Med-High

The Newborn and Nursing Pig

Prior to its birth, the young fetal pig is continually supplied with nutrients (amino acids, glucose, vitamins, and minerals) for its prenatal development. The fetus does not digest complex nutrients. The sow thus provides nutrients in a simple form to the developing pig until it is born, whereupon the form and the type of nutrients ingested and metabolized will change dramatically for the young pig.

Prenatal Nutrition and Development

The sow's placenta and umbilical cord are thick tissues that selectively transfer nutrients to the developing fetus. Water-soluble nutrients are more effectively transferred than those that are fat soluble. The pig is born with a low body-fat content and a low reserve of fat-soluble vitamins, particularly vitamin E. There is also a relatively low supply of iron and selenium transferred to the fetus. The neonatal pig must therefore be supplied with these and other nutrients, either from colostrum, milk, or an exogenous source.

The major dietary energy source provided to the fetus during its development is glucose, which is supplied from the maternal blood supply through the umbilical cord. Fetuses positioned toward the center of the uterine horn receive the largest supply of nutrients, resulting in pigs that are larger at birth, whereas those pigs positioned toward the end of the horn receive less glucose and other nutrients and thus generally have a lower birth weight. Birth weight of the pig is therefore largely determined by the amount of glucose transferred to the fetus. Pigs that have heavier birth weights have also demonstrated a more rapid growth rate from birth to market weight. An excess as well as an inadequate quantity of dietary energy can, however, be detrimental to the sow.

Amino acids cross the placenta for the development of muscle cells, organs, and other protein-containing tissues. Although the number of muscle cells is largely genetically determined by the parental genotype, fetal pigs that receive an inadequate supply of amino acids will have cells that are less physiologically mature by the time of birth. Under this condition, the subsequent growth rate of these pigs to market weight will be reduced.

Postnatal Nutrition

For those pigs that succeed in surviving the initial few days of life (e.g., 85 to 95%), their body weight approximately doubles during each subsequent week of life to at least three weeks of age. This demonstrates that there is a large quantity of nutrients supplied through the milk to the litter.

The neonatal pig contains less than 2% body fat and almost no subcutaneous fat. Consequently, the young pig must be provided a large amount of energy from fat or carbohydrate in the colostrum in order to survive. Because of the low body-fat covering, the newborn pig must have supplemental heat to prevent chilling and to maintain a normal body temperature. If the floor and room temperatures are below the pig's comfort zone, heat pads and/or heat lamps provide an effective source of supplemental heat.

Colostrum consumption is critical for the survival of the neonatal pig for several reasons, namely that of supplying nutrients and antibodies. Antibodies are not transferred across the placenta to the developing fetus, but can be transferred through mammary tissue into the milk. Because maternal antibodies do not reach the pig during fetal development, the consumption of colostrum antibodies are essential for the pig's health and survival postnatally. Antibodies are produced by the sow in response to vaccinations or subclinical disease exposure. These antibodies are transferred to colostrum and absorbed by the young pig during the initial 24 to 36 hours of birth but not thereafter. Colostrum gradually changes to a mature milk within three days of farrowing.

Because of the rapid growth-rate of the pig and the low concentration of iron in sow milk, the pig's requirement for this nutrient is not supplied in an adequate quantity. Iron is a component of hemoglobin that carries oxygen to the rapidly growing tissues. A supplemental source of iron must be administered to the pig within a few days of birth to prevent anemia. An intramuscular injection of 100 to 200 mg iron is the most common method of administration. Feeding iron salts to sows has been shown to prevent anemia in the nursing pig, but it is due to the resulting high iron content in the sow's feces, not to an increase in the iron content in the sow's milk. Because the young pig normally consumes some sow feces, the pig will ingest iron through this avenue. However, when pigs are farrowed in crates and the sow's excrement is passed directly into a pit, the pigs may not receive an adequate supply of iron from this source. After the pig is weaned, the scientific research evidence indicates that an iron injection is not necessary.

Sow milk (i.e., 3 to 21 days) is relatively constant in its protein, lactose, calcium, and phosphorus concentrations. Milk contains an excellent source of nutrients that are highly digestible (> 95%) by the pig. Certain milk constituents (e.g., selenium, vitamin E, fat) may, however, decline with increasing parity depending on the nutritional and body-condition status of the sow. Milk does not provide an adequate quantity of water for the young, rapidly growing nursing pig, and a waterer should be provided for the litter.

In this region of the United States, older sows are more prone to a deficiency in vitamin E and selenium than younger sows. Sow milks have lower selenium and vitamin E concentrations at the end of lactation, and these concentrations are lower in the milks of older sows. Consequently, the progeny of older sows are more likely to exhibit a deficiency of these nutrients at birth or within a week or two postweaning. The sow diet should be adequately fortified with these nutrients to prevent this deficiency.

Fat is not effectively used by the fetus, but becomes the major source of energy for the nursing pig. Fat is at a relatively high concentration in colostrum and in mature milk, ranging from 5 to 9%. The nursing pig is capable of effectively using the fat in sow milk. This is because sow-milk fat is emulsified when it is released by the milk gland, and the pig secretes a large amount of the enzyme lipase, both of which are responsible for breaking the fat down to its constituent fatty acids. The amount of fat in sow milk is largely influenced by genetics and the sow's body fat content, but it is also dependent upon the sow's lactation feed intake and the amount of fat in the lactation diet. Sows with a low body-fat content transfer less fat to the mammary glands. Adding fat to the sow's diet during the last phase of gestation has been shown to improve the survivability of lightweight pigs mainly by increasing the fat content of colostrum and milk. This allows the lightweight nursing pig to consume more energy. The addition of 5%

fat to the diet has not shown any detrimental effect on lactation feed intake, but does increase the sow's energy intake, increases milk fat content, increases pig weaning weight, reduces sow weight loss during lactation, and may shorten the weaning to rebreeding interval.

Sow milk does not contain an adequate quantity of nutrients to sustain the rapid growth of a young pig beyond 21 days of age. Under conditions of low milk production, creep feed should be provided to the litter. Normally, the young pig will "become interested" in a creep feed around 10 days of age, but the consumption of creep feed is quite variable among litters. If creep feed is fed, the Early-Wean dietary nutrient recommendation (Table 3) can be provided, but care should be taken to only add a small quantity per day to maintain freshness and prevent wastage. When sow milk production is low, the provision of commercial milk replacers and electrolytes to the pigs may be necessary if the sow is producing an inadequate quantity of milk, or if diarrhea is present in the young pigs.

Questions and Answers for the Newborn and Nursery Pig Section

Q. Is the composition of sow colostrum affected after inducing the sow to farrow two to three days early?

Yes. Milk secretion begins a few days prior to the birth of the litter. During this time, antibodies and nutrients are secreted or transferred into the mammary glands. If sows are stimulated to farrow early, the composition of the colostrum will be affected. It is preferable that the sow farrow at her natural time.

Q. Is colostrum always available for the neonatal pig?

Yes. Colostrum starts to be secreted about 10 hours prior to farrowing and is available on a continual basis post farrowing without the need for the suckling stimulus (up to 36 hours post farrowing).

Q. Is there an advantage to stomach tubing the neonatal pig with a "sugar" solution?

Nursing the sow and consuming colostrum shortly after birth is critical for pigs of any birth weight. Lightweight pigs have a minimal amount of energy stores at birth and can become hypoglycemic (low blood sugar) shortly after birth if they don't receive adequate nourishment. Research has demonstrated that administering a carbohydrate (e.g., dextrose) directly into the stomach of lightweight pigs can improve their survivability. In contrast, heavier-weight pigs can survive for a longer time without nursing and should not need a supplemental sugar source. Table sugar (i.e., sucrose) is **not** an acceptable sugar source and may cause extreme diarrhea and possible death of the neonatal pig, whereas glucose (hydrolyzed corn starch, dextrose) is a good carbohydrate source.

Q. When can pigs be effectively transferred to other sows, and what management techniques are effective in improving the chances of success?

Pigs should be transferred within one to three days after farrowing in order to procure a teat for nursing. The earlier pigs are transferred post farrowing, the better their acceptance by the sow and the better their subsequent performance. It is critical that young pigs receive colostrum immediately upon being born, either from their own mother or from the surrogate sow. It is essential that transferred pigs have access to teats when introduced to a new litter. A good management practice is to transfer pigs while the sow is nursing her own litter. Removal of all pigs, putting them in a box, and then reintroducing the litter in two to three hours is frequently used as a management practice. These procedures will allow the natural body odors of the sow's mammary tissue, which she uses for identification, to rub off on the pigs. In addition, the buildup of milk reserves in her mammary gland further encourages her to nurse the litter upon their introduction to the farrowing create.

Q. Because parity-one gilts produce less milk, should larger gilt litters be transferred to older, more mature sows?

Yes. Gilts or first-parity sows will consume approximately 15 to 20% less feed during lactation and also produce less milk than older sows. Equalizing litters between sows is a good practice, but having a smaller litter size on first-parity sows (eight to nine pigs) may result in larger pig weaning weights and better sow rebreeding performance.

Q. How early should an iron injection be administered?

The pig is born with a relatively low body reserve of iron. Because sow milk also supplies a limited amount of iron to the nursing pig, the young pig may show deficiency signs or anemia (slow growth rate, labored breathing, and pale skin) within seven to 14 days of age if additional iron is not given. The pig can be injected with iron (100 to 200 mg) anytime within the first week of life. To reduce additional handling of pigs, iron is generally injected at the time pigs are processed (e.g., clipping needle, etc.) without adverse effect.

Q. What sources of iron are effective for the young pig?

Iron is used for hemoglobin synthesis, which is essential for carrying oxygen in the blood to the pig's tissue. Injected iron is, however, complexed with a compound that will slowly release the iron into the blood system. This compound is generally a carbohydrate (e.g., dextrose, etc.). In the case of oral iron sources, it is not necessary that the iron be complexed with a carbohydrate, as iron absorption is regulated by the intestinal tract, particularly after "gut closure" occurs (24 to 36 hours of age). In the latter case, the iron must be in an available form. (See Table 2.) If pigs are raised on pasture, the soil will provide an adequate amount of iron for the nursing pig, which eliminates the need for an iron injection.

Q. Is it necessary to inject iron at weaning?

No. The 200 mg of iron injected at birth has been shown to provide an adequate amount of iron for approximately 28 to 35 days. If iron is supplemented in the starter diet in a form that has a high availability, and the pigs have normal feed consumption postweaning, there is no need to inject iron into the weaned pig regardless of pig genotype.

Q. What are the causes and symptoms of pig deaths after iron is injected in some litters (i.e., iron toxicosis)?

Research has demonstrated that when neonatal pigs are born extremely deficient in selenium and/or vitamin E and subsequently injected with iron, death may occur within a few hours of injection. This problem is more common with the pigs of older sows. Although the problem is attributed to an initial overload of iron, the cause is a selenium and vitamin E deficiency in the sow and subsequently in the newborn pig. Under this condition, the iron causes tissue damage (free radical formation). A good vitamin E and selenium status of the sow protects against this malady.

Q. Is there a benefit to injecting the newborn pig with vitamin E and selenium or in combination with iron?

Only in those herds having persistent vitamin E and selenium deficiency problems is there a need to consider injecting vitamin E and selenium into the pig shortly after birth. In contrast, iron is well recognized as being necessary for the young pig and must be administered within a few days of birth. Because colostrum is an excellent source of vitamin E and selenium for the young pig, it is better to make sure the sow is provided with an adequate quantity of vitamin E and selenium in the gestation diet and only to administer iron to the young pig.

The Starter Pig

Weaning pigs from 21 to 28 days of age is common among many commercial swine producers. The emergence of off-site nurseries is an increasingly popular attempt by producers to break the disease transfer between the sow and the litter. The use of highly digestible feeds for young swine has made weaning from 10 to 18 days popular. However, weaning early and/or weaning lightweight pigs poses several nutritional and management challenges.

The nutritional programs implemented for different weaning ages should reflect the animal's ability to digest the dietary feed components. It is therefore necessary to understand when to change from the more expensive starter diets to those less costly.

There are several physiological changes that occur in the digestive tract of the young pig from birth to eight weeks of age. The time of these changes will influence the decisions of what diets to feed. The transition in digestive enzyme development will therefore have a direct impact on the type of feedstuffs used in formulating starter pig diets.

Major challenges of the young weanling pig involve the **environment, health,** and **nutritional** conditions. An understanding of how each can affect the pig allows the swine producer to make wiser decisions in the nursery. To provide proper weaning conditions, pigs of a uniform weight should be fed together. Pig growth rate during the first weeks postweaning will affect their subsequent growth to market weight.

Environment

The physical environment (temperature, humidity, and air quality) in the nursery can directly influence the pig's performance. Unless the pig is placed in comfortable, draft-free conditions, the incidences of diseases and/or diarrhea may increase. As a result of poor environmental conditions, the effectiveness of a good diet in achieving good performance responses will be lost.

Evidence of good physical environmental nursery conditions can be best evaluated by observing pig behavior. Piling of pigs in their nursery pens reflects poor environmental conditions because the pigs are attempting to conserve body heat, whereas when pigs have distributed themselves over the entire floor, nursery conditions are either comfortable or perhaps too hot. The latter condition can be recognized by high respiration rates, and steps should be taken to relieve this situation.

Because of the poor feed intake and loss of body fat during the initial days postweaning, nursery room temperatures should be raised slightly from the temperature in the farrowing house. The nursery temperature can be subsequently lowered as pigs become older, heavier, and accumulate more body fat. The type of flooring, bedding, heat pads, hovers, and pen height from the floor will influence the "comfort zone" of the pig and therefore help to determine the desired nursery temperature. An understanding of pig behavior helps determine the best nursery-room temperature and other environmental conditions.

The recommended room temperatures of the nursery depend largely on the weight of the pig and the amount of body fat that has accumulated during the nursing period. The outer fat layer (backfat or subcutaneous fat) rapidly accumulates while the pig is nursing, but a substantial amount of this fat can be lost during the first week upon weaning. The subcutaneous fat layer of younger and/or lighter-weight pigs at weaning is also lower at weaning than that of heavier-weight pigs. This outer layer of body fat provides insulation from low temperatures. To be within their "comfort zone," lightweight pigs need a warmer nursery-room temperature than heavier-weight pigs (Figure 3). As pigs become heavier, they regain their subcutaneous fat and the need for the "hot nursery" condition becomes less.

Most pigs, but particularly those of a light weight, have a poor appetite upon weaning, resulting in body fat being lost upon weaning. This makes them prone to being the victims of poor performance or becoming "poor doers." This effect is frequently demonstrated by their "rough" look during the initial weeks postweaning. The inclusion of plasma protein and lactose in the diet has resulted in an increased feed intake during this early postweaning period. Pigs of a heavier weaning weight grow faster, not only while in the nursery but also to market weight, than pigs of a lighter weaning weight.

Digestive Tract Changes

The consumption of milk by the nursing pig results in the growth or proliferation of a group of bacteria (*Lactobacillus spp.*) in the stomach and intestinal tract. These bacteria use some of the lactose in milk to produce lactic acid, which lowers the pH in the stomach. This acidic condition aids the digestion process and prevents the growth of other microorganisms, some of which may be detrimental to pig performance. After the pig is weaned or when milk products are eliminated from the starter diet, these bacteria are quickly reduced in number, whereupon other bacteria become established in the intestinal tract. If pathogenic bacteria are allowed to predominate during this transition period, diarrhea, disease, and weight losses can occur. The health status of weaned pigs, particularly those transported long distances, should be closely monitored during the initial weeks postweaning.

Sow colostrum contains antibodies that are directly absorbed through the pig's intestinal tract during the first 24 to 36 hours of life, but another group of antibodies (IgA) is also present in the mature milk of the lactating sow. These latter antibodies are not absorbed, but remain in the intestinal tract, attach to the villi, and protect the intestinal lining against pathogenic bacteria. After the pig is weaned, these milk antibodies (IgA) no longer are supplied. Until the pig develops its own immune system, the intestinal tract of the pig is susceptible to disease conditions.

Nutrients are absorbed in the small intestine through microscopically elongated villi. Although digestive enzymes are produced by the pancreas, the tips of the villi in the small intestine also contain digestive enzymes. Upon weaning, the villi become shorter in length, and the digestive enzymes from the villi are temporarily lost. Consequently, when the villi length becomes shortened, the absorptive area and the overall digestive capacity of the weaned pig is reduced. The inclusion of plasma protein, zinc oxide, and lactose from dried whey in the initial starter diet has been shown to prevent or reduce the severity of the postweaning lag which is frequently encountered by young weanling pigs.

The secretion of digestive enzymes and the types of enzymes secreted by the young pig are dependent upon the age, weight, and diet fed to the pig. Although the nursing pig can effectively secrete enzymes for the digestion of colostrum and milk products, the enzymes necessary to digest the more complex components of plant and other animal products are inadequately secreted by the young pig. As the pig matures, its ability to secrete the enzymes necessary for digesting the complex protein and starch components of plant and animal products increases (Figure 6). When the pig is weaned at a younger age or is lighter in body weight, its ability to produce these digestive enzymes is lower than older pigs or pigs weaned at heavier weights. Consequently, the digestion of the complex dietary components is poorer with lighter-weight pigs. Feeds used in the diets of younger and lighter-weight pigs during the early weeks postweaning should closely match the pig's enzyme production profile. As the pig becomes older and heavier, the pig can effectively digest higher dietary concentrations of complex plant and animal products. The transition to less costly diets at appropriate pig weights and time postweaning will allow optimum performance during the entire nursery period.

Because of the digestive enzyme transition that the pig goes through from birth to eight weeks of age, the changing morphology of the intestinal villi, and the necessity of initially using specialized feed sources during the early phases postweaning, a phase-feeding program is highly recommended during the entire starter period. The use of specialized feed components (e.g., plasma protein, milk products, soy protein concentrate, etc.) has increased the cost of early weaning diets, but appears to be essential during the period that the gut is maturing. The production phases and nutrient recommendations for these periods are presented in Table 3. Although this nursery feeding program is now popular, phase feeding has always been used with grower-finisher pigs, but diets in the nursery period are changed more frequently. Pigs that are weaned at heavier weights will also benefit from at least a short-time feeding of the initial starter diet. The premature changing to a less costly diet may be economically appealing but can cause unthriftiness and poor pig uniformity. It is therefore suggested that the change of diets to the latter phases be based largely on pig weight, not pig age. All weaned pigs should receive the initial starter diet for at least a short time (seven to 14 days) postweaning. It is recommended that an early weaning diet be fed to pigs lighter than 8 lb. (regardless of pig age), with the Starter-1 nutrient levels fed from 12 to 15 lbs., the Starter-2 dietary requirements to 25 lbs., and the Starter-3 recommendations provided until the pig reaches 50 lbs. body weight.

Table 3. Nutrient Recommendations for Starter Pigs.

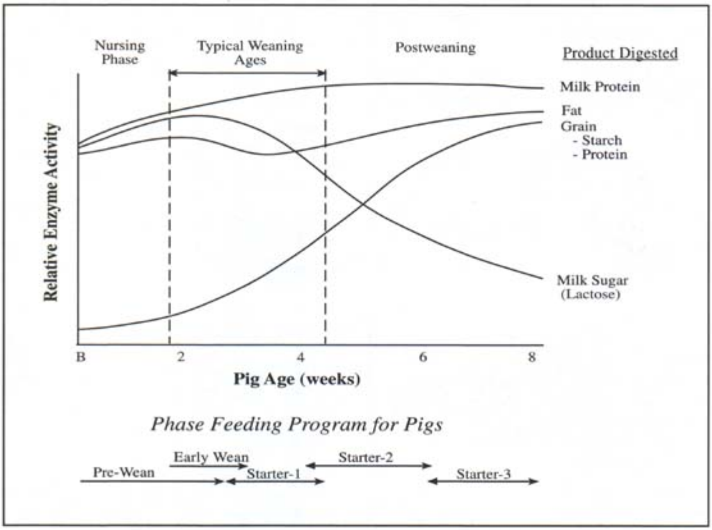
Item	Starter Phase			
	Early-Wean	Starter-1	Starter-2	Starter-3
		Expected Performance Responses		
Body weight, lb.	8-12	12-15	15-25	25-50
Days of age	10-18	18-28	21-35	28-56
Daily gain, lb.[a]	0.20-0.50	0.30-0.60	0.60-0.90	0.90-1.25
Daily feed, lb.	0.30-0.70	0.50-0.90	0.75-1.30	1.30-1.80
Feeding duration, days	7-10	7-10	10-18	12-18
	Major Dietary Nutrient Recommendations (As-Fed Basis)[b]			
Protein, %	20-24	18-22	18-20	18-20
Amino acids (total)[c]				
Lysine, %	1.65	1.40	1.30	1.15
Tryptophan, %	0.25	0.22	0.20	0.18
Threonine, %	0.95	0.85	0.75	0.70
Methione + Cystine, %	0.85	0.80	0.72	0.64
Macro-minerals[c]				
Calcium, %	1.00	0.90	0.90	0.90
Phosphorus (total), %	0.80	0.70	0.70	0.70
Phosphorus (available), %	0.55	0.45	0.45	0.45
Sodium, %	0.35	0.30	0.20	0.20
Chloride, %	0.35	0.30	0.18	0.18
Trace-minerals[d]				
Copper, ppm	10	10	10	10
Iodine, ppm	0.15	0.15	0.15	0.15
Iron, ppm	100	100	100	100
Manganese, ppm	20	20	20	20
Selenium, ppm	0.30	0.30	0.30	0.30
Zinc, ppm	125	125	125	125
Vitamins[d]				
Vitamin A, IU/lb.	1,200	1,200	1,200	1,200
Vitamin D, IU/lb.	120	120	120	120
Vitamin E, IU/lb.	30	30	30	20
Vitamin K, mg/lb.	4	4	2	2
Biotin, mg/lb.	0.10	0.10	0.10	0.10
Choline, mg/lb.	200	200	100	100
Niacin, mg/lb.	15	15	12	12
Riboflavin, mg/lb.	8	8	6	6
Pantothenic acid, mg/lb.	10	10	7.5	7.5
Vitamin C, mg/lb.	35	30	0	0
Vitamin B_{12}, µg/lb.	20	20	15	15

Continued on the next page

Table 3 (continued). Nutrient Recommendations for Starter Pigs.

[a] A range is denoted that reflects different environmental and facilities conditions. It also reflects starting and ending performance measurements within a production phase.
[b] These nutrients reflect those that normally need to be supplemented to practical diets. The complete list of nutrients required is greater than those indicated. Feed grains normally supply an adequate quantity of many nutrients.
[c] Values reflect total dietary level (indigenous + supplemental).
[d] Values reflect the supplemental level to be added to the diet.

Figure 6. Enzyme Development in the Pig from Birth to 8 Weeks of Age.



Questions and Answers for the Starter Pig Section

Q. How critical is it to use a dietary antibiotic in the starter phase?

Research conducted with various types of nursery conditions has almost universally demonstrated a 10 to 20% improvement in performance responses when antibiotics or antibacterial agents are used during the starter period. The magnitude of the gain and feed-conversion improvements largely depends upon the animal's health status, the cleanliness, environmental, and management conditions within the nursery facility. The better the sanitation conditions, the smaller will be the performance differences. Selection of an appropriate antibiotic should be in consultation with university Extension specialists, technical service individuals associated with the feed industry, and/or your veterinarian.

Q. Should zinc oxide and/or copper sulfate be used throughout the starter phase?

High dietary levels of zinc oxide and/or copper sulfate have been found to enhance the growth rate of weaned pigs by approximately 15%. Concentrations up to 3,000 ppm zinc and/or 250 ppm copper have been found to result in this growth response. In some cases, the combination of these two mineral sources has had an additive effect on pig growth responses, while in other cases the use of one source appears adequate. It is, however, necessary to use the zinc oxide form. The growth response will be obtained throughout the starter phase, but the use of high zinc levels should be discontinued after three to four weeks.

Q. I receive two-week-old pigs for my nursery from two states away. How should I start these pigs on their nursery diets, and what diets should I feed them?

Because transported pigs will most likely arrive in a dehydrated state, the most important nutritional item for consideration upon their arrival is to provide an ample quantity of water. An essential management practice is to make sure the environment is comfortable and dry. Sprinkling the starter diet or a small quantity of oat groats on the mat close to the feeder allows the pigs to become acquainted with the feeder. Starting pigs on feed correctly and making sure they consume water and feed are critical.

Q. How long should I feed a Starter-1 diet to two- and three-week-old pigs that were light in weight at weaning?

There is a long-term benefit to feeding a Starter-1 diet for at least one week and preferably two weeks to all nursery pigs. Lightweight pigs, particularly those weaned at two weeks that weigh eight pounds or less, should be fed a Starter-1 diet for at least two weeks and preferably to a body weight of 15 pounds before changing to the Starter-2 diet.

Q. How much plasma protein should be included in Starter-1 and -2 diets?

Spray-dried plasma protein from swine or cattle blood is equally effective and has been a major contribution to the success of early weaning programs. The product is, however, expensive, and its dietary level and length of feeding should be closely monitored. With extremely early (< 10 days) or lightweight (< 8 lb.) pigs, the diet should contain 5 to 7% plasma protein, whereas pigs from 18 to 21 days of age should have a diet that contains 3 to 5% plasma protein. Lower dietary inclusion levels of less than 3% are frequently used in an effort to reduce feed costs. When added at levels greater than 5%, other amino acids (e.g., methionine) may need to be added to the diet.

Q. Are starter pigs sensitive to soybean meal?

Raw soybeans or poorly processed soybean meal contains a protein (ß conglycinin) that serves as an antigen (stimulates the immune system) in the intestinal tract. Younger animals are more sensitive to this soybean protein than older animals. Soybeans that have been processed to destroy much of this antigenic factor have been produced (isolated soy protein concentrates), but they are more expensive than soybean meal. The inclusion of plasma protein and lactose in the Starter-1 diet has been shown to lessen the antigenic effect of soybean meal.

Q. How important are oats in the diets of weaned pigs?

Oats appear to be one of those feed ingredients that is "well-liked" by young animals, and they consume them readily. Oat protein is of high quality, and the carbohydrate is highly digestible. However, oats can be a fairly expensive feedstuff compared to other grains. Dehulled oats (oat groats) are more digestible than whole oats but are also more costly. When dehulled oats are used, a level of 10% is recommended and should be removed after the Starter-1 diet is withdrawn. The hull of whole oats contains fiber that has a low digestibility.

Q. Do I need fishmeal in starter diets?

Fishmeal is an ingredient that can either be of high or poor quality, depending on its source of origin and the processing method used to dry it. Fishmeal (select grade) contains a source of protein (amino acids) that can be used effectively by weanling pigs. When the cost is competitive on a lysine basis, dietary levels of 20% have been used in pig starter diets; but in most cases 2.5 to 10% is the more common level. The decision to use the product should be based on its relative cost of lysine contributed and the quality of the product.

Q. I can purchase some sugar products at a local bakery or from an ingredient supplier. Can I substitute these for lactose in starter pig diets?

Many by-products high in milk products or processed cereals contain high levels of simple carbohydrates (glucose, sucrose, and fructose) and are an effective replacement for lactose in starter pig diets. The manufacturer of these products should be able to provide you with the composition of the product and oftentimes the results of weanling pig research studies.

Q. My veterinarian has diagnosed mulberry heart disease in my pigs and suggests I use high levels of vitamin E. What is the current recommendation?

High levels of vitamin E (100,000 IU/ton) appear to be of some benefit in reducing the mulberry heart condition in pigs in many but not all cases. Research has, however, not consistently shown that high levels of vitamin E or selenium in the starter diets can prevent or eliminate this problem. An improved vitamin E and selenium status of the sow would be of greater benefit in preventing this disease condition in weaned pigs.

Q. My pigs demonstrate excessive bleeding upon birth or castration. What is the cause and how can this be prevented?

Excessive bleeding occurs when vitamin K is inadequate in the animal's body. Vitamin K is either synthesized in the intestinal tract by microorganisms or it is provided in the diet as vitamin K (menadione). The presence of molds in the diet or extremely high dietary levels of antibiotics can interfere with vitamin-K synthesis in the intestinal tract. A vitamin-K injection and/or proper fortification levels to the sow and pig diets should prevent the problem.

Q. Should I split the sexes in the nursery for better performance responses?

From a nutritional standpoint, there is no reason to split the sexes this early; however, you would be handling smaller pigs which will prevent later sorting and pig-fighting problems.

Q. Should Vitamin C be added to my starter diets?

Research evidence suggests that the pig, upon weaning, will have an improved growth rate to 35 days of age when vitamin C is added to the diet. As pigs are weaned earlier or are lighter in body weight, there is a greater chance of attaining the positive responses from vitamin C. It is critical that a stabilized form be used when the vitamin is incorporated in the starter diet.

Q. How effective are the wean to finish facilities?

This is a relatively new concept in the swine industry where weaned pigs are placed in a pen and remain there until they reach market weight. If the environment and health status of the young pigs can be maintained postweaning, this type of facility has produced good results. Obviously more total pens are needed, as the pigs will remain in these pens for at least five to six weeks longer than if they had been placed in the pens at 40–60 lbs.

The Grower-Finisher Pig

The grower-finisher period has been considered to be the least complicated segment of swine production, but with newer genotypes and feeding strategies, it is becoming somewhat more complex. Approximately 75 to 80% of the total feed used per 100 lb. of pork marketed is consumed during this period, representing approximately 50 to 60% of the total cost of pork production. Several factors can, however, affect the grower-finisher pig's nutrient requirements. Those factors of greatest influence on the pig's growth rate and nutrient requirements are genetics, sex, herd health, environmental temperature, and stage of development. Nutrient recommendations for grower-finisher pigs of differing genotypes and for gilts and barrows within each genotype are presented in Tables 4 and 5.

Genetics

Pigs differ in their genetic potential to deposit lean (muscle) and fat tissue, and in the pattern of development of these tissues. Some genotypes gain both of these body-component tissues rapidly throughout the grower-finisher period, whereas others gain both lean and fat slowly. Other genetic lines fit into a slow-rapid or rapid-slow pattern of these two body components. High lean-gain pigs are defined in this publication as pigs that deposit lean (fat-free muscle) tissue at 0.7 lb. or higher per day during the grower-finisher period. This generally results in > 50% fat-free lean in the carcass at slaughter and a 10th rib backfat thickness of 0.6 to 0.9 inches. Although there are leaner pigs available, this is considered leaner than the "industry average" pigs. The latter group is considered to have < 49% fat-free lean, and a 10th rib backfat thickness of 0.9 to 1.3 inches.

The rate and composition of weight gain during the grower-finisher period can affect the amino acid and energy needs of the pig perhaps more than other nutrients. A rapid rate of lean gain increases the need for amino acids because these nutrients are used for protein synthesis, most of which is muscle tissue. On the other hand, lean deposition will require less energy than fat deposition.

To formulate diets accurately for different genetic lines, it is necessary to know the rate and pattern of lean deposition and the feed intake for the specific genetic line. Unless the seedstock supplier provides this information for the progeny from their genetic line, the collection of feed intakes at two- to three-week intervals and subsequent slaughter data with market pigs may be desirable. This will allow one to better formulate the diets for the herd. As we gain information about specific amino acid and mineral needs for body growth, we will be able to calculate the pig's nutrient requirements more precisely. Currently, the most accurate method for assessing the lean composition of the pig is to measure the backfat thickness and the loin muscle area with a ruler and grid, respectively, after a group of pigs have been slaughtered. The formulas presented here are currently used to calculate the amount of lean deposited per day. ("Days on test" in the formulas presented refers to the length of the entire feeding period.)

When carcass measurements are available, daily lean gain can be determined by the general formula presented. The information calculated can therefore be used to determine the lean gain per day. The recommendations in Tables 4 and 5 can be used to balance the diets for the genotype of the pigs you are feeding.

LEAN GAIN = (lbs. of lean in carcass at slaughter) - (lbs. of initial lean in feeder pig)

$$\text{Lean Gain} = \frac{0.95 \times \left[\begin{array}{c} 7.231 + 0.437 \times \text{adj. warm carcass wt., lb.} \\ -18.746 \times 10^{th} \text{ rib fat depth, in.} \\ +3.877 \times 10^{th} \text{ rib LMA*, in.}^2 \end{array}\right] - [(0.418 \times \text{live wt., lb.}) - 3.65]}{\text{Days on test}}$$

When fat and muscle depth data are obtained electronically, the following formula can be used:

$$\text{Lean Gain} = \frac{0.95 \times \left[\begin{array}{c} 2.827 + 0.469 \times \text{adj. warm carcass wt., lb.} \\ -18.470 \times \text{fat depth, in.} \\ +9.824 \times \text{muscle depth, in.} \end{array}\right] - [(0.418 \times \text{live wt., lb.}) - 3.65]}{\text{Days on test}}$$

*LMA = loin muscle area

Sex

Gilts usually gain weight less rapidly than barrows, particularly above 100 lbs. body weight. Gilts generally deposit the same amount of lean tissue per day as barrows but deposit a lower quantity of fat because of the lower amount of feed or energy consumed. Gilts are therefore somewhat older and leaner by the time they reach market weight. Consequently, because of the lower feed intake but a similar amount of body lean tissue, gilts require a higher concentration of amino acids in their diets than barrows. Gilts may, however, exhibit estrus in the finisher pen before they reach slaughter weight, which can affect the other pigs' feed consumption and daily gain. Consequently, it is desirable to feed gilts and barrows in separate pens.

Barrows consume more feed than gilts, particularly during the finisher phase. This in itself accounts for some of the higher carcass fatness in barrows. Consequently, the addition of fat to finisher diets may be beneficial for gilts who have a lower energy intake, but could be detrimental for barrows who have a proportionally higher feed intake. Five percent added fat to the diet increases the backfat thickness of industry average pigs by approximately 0.08 inches.

Because of the sex and feed-intake differences, **split-sex** feeding allows for the more precise formulation of diets to meet the nutrient needs of barrows and gilts. Splitting pigs by sex to different pens at weaning or at the start of the grower period allows the producer to market leaner gilts and to feed barrows more economically. It also results in pigs of a more uniform weight within each pen.

Herd Health

It is difficult to quantify "healthy" pigs, but pigs of a high health status gain weight more rapidly and are more efficient in feed utilization than pigs that have clinical or subclinical disease conditions. Healthy pigs will more nearly reach their genetic potential for growth. High-health-status pigs gain lean more rapidly, but they also deposit fat at a faster rate. The inclusion of antibiotics or antibacterial agents in the diets of market pigs has consistently shown a growth and feed conversion improvement. Generally, grower pigs show a greater benefit than finisher pigs when antibiotics are added to their diets.

Environmental Temperature

Low ambient temperatures stimulate the pig's appetite and thus its feed intake because additional energy is required to maintain the pig's body temperature. Body temperature is regulated after heat is released from both the digestion and tissue metabolism of carbohydrates, fats, and proteins. The heat generated by the digestive and metabolic process of feeds is called "heat increment." This heat can be beneficial as well as detrimental to subsequent pig performance. Dietary fat results in a lower amount of heat released during the digestion and metabolic process and thus has a low heat increment. Dietary protein and fiber release more heat during the digestion and metabolic process, and these feed components therefore have a high heat increment. High ambient temperatures can depress the pig's feed intake. Consequently, when the pig is stressed by high environmental temperatures or from high body heat, the pig attempts to produce less heat by consuming less feed. Consequently, the incorporation of fat into the pig's diet will have less of a detrimental effect on the pig's feed intake at a high ambient temperature because less heat is being generated and less body heat will need to be dissipated. Supplemental dietary fats/oils may therefore be helpful when hotter environmental temperatures are expected. In contrast, because high fiber feeds result in a higher heat increment, diets with a higher fiber content will be more beneficial during colder temperatures where the additional heat generated from the digestive process is used to keep the body warm. However, diets high in fiber content can be detrimental in a hot environment. Pigs fed in drylots or open-front buildings require more energy to maintain their body temperature during the colder seasons than pigs fed in complete confinement where conditions are temperature-controlled.

Stage of Maturity

When expressed as a percentage of the diet, most nutrient requirements change with age or maturity (Figure 5). Although this change occurs daily, under practical conditions it is not feasible or necessary to reformulate the pig's diet that frequently. Feeding several diets (phase feeding) during the grower-finisher period will lower feed costs, but there may not be much difference in the rate of gain. One of the more important considerations in the phase feeding of pigs from 50 lbs. to market weight is that excess nutrients are not being fed when the pig does not need them, and therefore there is less wastage of nutrients in the excrement. The number of diets used in a grower-finisher feeding program will usually range between three and six.

Some have advocated the withdrawal of dietary vitamins and minerals during the last four to six weeks of the finisher period. This practice could affect the nutrient content of the meat, which is one of the desirable attributes of pork. It should be recognized that when pigs are growing, they have a metabolic as well as an immunological need for vitamins and minerals. If the pig is challenged by an infectious disease, the immune system may not function optimally if the body becomes deprived of critical nutrients. Although body tissues can store some vitamins and minerals for a short time period, they will divert nutrients from body stores to meet their metabolic needs, thus depleting body tissue reserves. Because nutrient withdrawal from the diet may affect the nutritional value and shelf life of pork, the practice is not recommended.

Feed Wastage

Feed wastage is difficult to measure in most swine facilities. However, it is generally acknowledged that if feed is observed to be outside the feeder, at least 10% of the feed is being wasted. Commercially available feeders have been found to have feed wastage that ranges from 1 to 34%. The selection of a good feeder and its proper adjustment are critically important to reduce feed wastage. The feeder should be checked daily to assure the proper flow rate and accessibility of feed to the pig. A properly adjusted feeder has approximately 1/4 to 1/2 of the bottom pan lightly covered with feed, indicating an adequate feed flow rate. The addition of water to the feed "wet feeding system" has been shown to reduce feed wastage and improve feed efficiency by 5 to 8%. However, frequent feeder adjustments and the removal of wet, unused, or older feed may increase the amount of labor needed to achieve this efficiency. The addition of water to the feeders may reduce water wastage by 40 to 50% during the summer, but the growth of molds in the feeder must be closely monitored when this type of feeder is used.

Table 4. Nutrient Recommendations for Grower-Finisher Pigs (High Lean-Gain, High Health).

Item	Weight Range: 50 to 100		100 to 150		150 to 200		200 to Market	
Weight, lb.: / Sex:	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow
Expected Performance Responses[a]								
Daily gain, lb.	1.5-1.8	1.7-2.0	1.6-2.0	1.7-2.0	1.6-2.1	1.7-2.2	1.6-2.1	1.6-2.3
Daily feed, lb.	3 - 4	3.5-4.5	4 - 5	4.5-5.5	4-6	4.5-7	4.5-7	5-8
Daily feed, lb. (amount to obtain suggested lysine)	3.6	3.7	4.6	4.7	5.1	5.3	5.6	5.9
Dietary Recommendations (As-Fed Basis)[b]								
Protein, %	18- 22	17- 20	17- 20	16- 19	16- 19	15- 18	14- 17	13- 16
Amino acids (total),[c,d]								
Lysine, %	1.10	0.95	1.00	0.85	0.90	0.75	0.75	0.60
Lysine, g/day	18	16	21	18	21	18	19	16
Tryptophan, %	0.20	0.17	0.18	0.15	0.16	0.14	0.14	0.11
Threonine, %	0.72	0.62	0.65	0.55	0.58	0.49	0.49	0.39
Methionine + Cystine, %	0.66	0.57	0.60	0.51	0.54	0.45	0.45	0.36
Macro-minerals[d]								
Calcium, %	0.72	0.72	0.72	0.72	0.58	0.58	0.58	0.58
Phosphorus (total), %	0.60	0.60	0.60	0.60	0.48	0.48	0.48[e]	0.48[e]
Phosphorus (available), %	0.30	0.30	0.30	0.30	0.21	0.21	0.21	0.21
Sodium, %	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Chloride, %	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
(Salt, %)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace minerals[f]								
Copper, ppm	7	7	7	7	7	7	7	7
Iodine, ppm	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Iron, ppm	85	85	85	85	55	55	55	55
Manganese, ppm	7	7	7	7	6	6	6	6
Selenium, ppm	0.3	0.3	0.2	0.2	0.15	0.15	0.15	0.15
Zinc, ppm	85	85	85	85	55	55	55	55
Vitamins[f]								
Vitamin A, IU/lb.	1000	1000	1000	1000	1000	1000	1000	1000
Vitamin D, IU/lb.	110	110	110	110	110	110	110	110
Vitamin E, IU/lb.[g]	22	22	22	22	11	11	11	11
Vitamin K, mg/lb.	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

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Table 4 (continued). Nutrient Recommendations for Grower-Finisher Pigs (High Lean-Gain, High Health).

	Weight Range							
Weight, lb.:	50 to 100		100 to 150		150 to 200		200 to Market	
Item / Sex:	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow
Dietary Recommendations (As-Fed Basis)[b]								
Niacin, mg/lb.	11	11	11	11	8	8	8	8
Riboflavin, mg/lb.	3	3	3	3	2.5	2.5	2.5	2.5
Pantothenic acid, mg/lb.	8	8	8	8	7	7	7	7
Vitamin B_{12}, µg/lb.	11	11	11	11	6	6	6	6

[a] A range is denoted that reflects different environmental conditions.
[b] These nutrients need to be supplemented to diets. Other nutrients are usually adequate.
[c] If gilts and barrows are fed together, use an average of the values given.
[d] Values are total dietary levels.
[e] The phosphorus level can be reduced to 0.35% during this phase if calcium is at the same time reduced to 0.40%.
DO NOT FEED THESE LOW Ca and P DIETS to REPLACEMENT GILTS!
[f] Values are supplemental levels.
[g] The vitamin E level needs to be increased as the unsaturated fatty acid (PUFA) level in the diet increases. (3 IU Vit. E/g PUFA).

Table 5. Nutrient Recommendations for Grower-Finisher Pigs (Industry Average).

Item / Weight, lb.: / Sex:	50 to 100		100 to 150		150 to 200		200 to Market	
	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow
Expected Performance Response								
Daily gain, lb.	1.1-1.6	1.1-1.6	1.4-1.8	1.4-1.8	1.5-2.0	1.5-2.0	1.6-2.1	1.6-2.1
Daily feed, lb.	3-5	3-5	4-6.5	4-6.5	4-7	4.5-7.5	4.5-8.5	5-9
Daily feed, lb. (amount to obtain suggested lysine)	3.5	3.6	4.6	4.9	5.5	6.0	6.0	6.4
Dietary Recommendations (As-Fed Basis)[b]								
Protein, %	17-20	15-18	16-19	14-17	15-18	13-16	13-15	12-14
Amino acids (total)[cd]								
Lysine, %	0.95	0.85	0.82	0.72	0.72	0.63	0.63	0.55
Lysine, g/day	15	14	17	16	18	17	17	16
Tryptophan, %	0.17	0.16	0.15	0.13	0.13	0.11	0.11	0.10
Threonine, %	0.62	0.55	0.53	0.47	0.47	0.41	0.41	0.36
Methionine + Cystine, %	0.57	0.51	0.49	0.43	0.43	0.38	0.38	0.33
Macro-minerals[d]								
Calcium, %	0.65	0.65	0.60	0.60	0.50	0.50	0.45	0.45
Phosphorus (total), %	0.55	0.55	0.50	0.50	0.45	0.45	0.40[e]	0.40[e]
Phosphorus (available), %	0.28	0.28	0.23	0.23	0.20	0.20	0.15	0.15
Sodium, %	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Chloride, %	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
(Salt, %)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace minerals[f]								
Copper, ppm	6	6	6	6	6	6	6	6
Iodine, ppm	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Iron, ppm	75	75	75	75	50	50	50	50
Manganese, ppm	6	6	6	6	5	5	5	5
Selenium, ppm	0.3	0.3	0.2	0.2	0.15	0.15	0.15	0.15
Zinc, ppm	75	75	75	75	50	50	50	50
Vitamins[f]								
Vitamin A, IU/lb.	900	900	900	900	900	900	900	900
Vitamin D, IU/lb.	100	100	100	100	100	100	100	100
Vitamin E, IU/lb.[g]	20	20	20	20	10	10	10	10
Vitamin K, mg/lb.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Continued on the next page

Table 5. (continued) Nutrient Recommendations for Grower-Finisher Pigs (Industry Average).

Item	Weight, lb.:	50 to 100		100 to 150		150 to 200		200 to Market	
	Sex:	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow
		Dietary Recommendations (As-Fed Basis)[b]							
Niacin, mg/lb.		10	10	10	10	7	7	7	7
Riboflavin, mg/lb.		2.5	2.5	2.5	2.5	2	2	2	2
Pantothenic acid, mg/lb.		7	7	7	7	6	6	6	6
Vitamin B_{12}, μg/lb.		10	10	10	10	5	5	5	5

[a] A range is denoted that reflects different environmental conditions.
[b] These nutrients need to be supplemented to diets. Other nutrients are usually adequate.
[c] If gilts and barrows are fed together, use an average of the values given.
[d] Values are total dietary levels.
[e] The phosphorus level can be reduced to 0.30% during this phase if calcium is at the same time reduced to 0.34%.
DO NOT FEED THESE LOW Ca and P DIETS to REPLACEMENT GILTS!
[f] Values are supplemental levels.
[g] The vitamin E level needs to be increased as the unsaturated fatty acid (PUFA) level in the diet increases. (3 IU Vit. E./g PUFA).

Questions and Answers for the Grower-Finisher Section

Q. How much synthetic lysine can be used to replace soybean meal?

Three and one-half pounds of feed-grade lysine (78.8% lysine) and 96.5 pounds of corn can replace 100 pounds of soybean meal. A higher amount may lead to threonine and tryptophan deficiencies.

Q. Can we increase the shelf life of pork by feeding higher dietary levels of vitamin E?

This effect is not as well documented in pork as it is in beef. High levels of vitamin E will reduce drip (water) loss and improve pork color, but the benefits and economics are unknown at the present time.

Q. Should antibiotics, copper sulfate, or dewormers be added to finishing feed?

Antibiotics are of benefit in some herds but not in all conditions. The response is usually less during the finisher period. Pigs housed in dirtier facilities that have manure buildups will more likely result in a beneficial response to antibiotics or antibacterial agents. Dewormers will be of benefit only if pigs are exposed (infected) with worms.

Q. What about limit feeding finishing pigs?

Limit feeding to approximately 85% of full feed improves leanness and feed efficiency but will result in lower weight gains. Industry average barrows may benefit most from limit feeding, by preventing them from becoming too fat.

Q. When should I start split-sex feeding?

Split-sex feeding should be initiated no later than 50–75 lbs.

Q. Will extra vitamins and minerals correct feet and leg problems?

Providing animals with higher dietary levels of these nutrients on a short-term basis has not been shown to be beneficial. Although certain vitamins (e.g., biotin) and minerals have been shown to affect feet and leg development, these nutrients need to be fed throughout the life cycle of the pig.

Q. Does the type of waterer make any difference?

Assuming an adequate water flow rate, the type of waterer has had little effect on performance, but may affect water wastage.

Q. Can I use poorer quality feeds in the grower-finisher period?

Poorer quality feeds may adversely affect pig performance, but it is better to feed these materials to the grower-finisher pig than to weaned or breeding animals. It is best to feed the material in question to a small group of "test" animals to evaluate the "feed refusal" response. It is recommended that the feed be analyzed for mycotoxins.

Q. Do pigs that are housed at high density require a different diet?

No. Even though pigs have less than optimal pen space and may eat less feed, they do not benefit from diets with higher concentrations of nutrients.

Q. How important is it to clean facilities between groups of pigs?

The higher the sanitation level that can be maintained in the facilities, the greater will be the performance benefit from the pigs.

Q. Since I feed pigs outdoors on dirt lots, what additional nutritional factors need to be considered?

The primary factor to consider is energy level during cold or hot seasons. Access to good quality water is critical, and deworming programs are essential.

Q. Should I provide free-choice minerals for my pigs?

No. Remember, "extra" minerals are of no benefit. Pigs have a tendency to waste minerals when fed "free choice."

Q. My pigs seem to stop growing at about 180 pounds. What is the cause of this, and how can I prevent this?

This condition, commonly called "stall out," is frequently a result of subclinical disease. High environmental temperatures may also play a role. Management practices such as segregated early weaning, all-in/all-out production, and/or three-site production with excellent sanitation and biosecurity may resolve the problem.

Q. What is the cause and how can I prevent tail biting?

Although a great amount of research has been done on this, the question has not been answered. It is apparent that tail clipping is helpful, but there is no known nutritional remedy for this condition. Some research evidence suggests that sprinkling salt on the floor has been helpful.

The Replacement Gilt

A great deal of genetic progress has recently been achieved towards "specific" breeding schemes. This has led to the development of maternal lines which are genetically selected for large litters and high milk production. These improved genotypes are typically crossbred animals that have a docile temperament and a white hair color, but they also have demonstrated a lower lactation feed intake. When mated to a "terminal line" boar, the progeny have a high lean-tissue production.

Rearing

Several maternal lines that are being used in the industry today are classified as "high-lean" or "high-producing" (>0.7 lb. fat-free lean per day) animals. These genetic lines should be fed diets that will maximize their lean gain during the first six months of life, but upon entrance into the replacement pool or breeding herd, their body fat content should be emphasized more than during the grower-finisher period. Other maternal lines have an "average" ability to deposit lean (< 0.7 lb. fat-free lean per day). The dietary amino acid concentrations provided during the grower-finisher period should reflect the lean growth potential of the animal. The amino acid requirements of the high-producing replacement gilt are generally similar to those of the high-lean gain grower-finisher pig (Table 4).

Most of the vitamin and mineral requirements for replacement gilts are similar to that of the grower-finisher pig. Replacement gilts, however, should be fed higher dietary levels of vitamin A, vitamin E, calcium, phosphorus, selenium, copper, and zinc than market hogs. This is done to enhance their body reserves of specific nutrients that are needed at higher levels during future reproductive purposes and/or to enhance their immune response (Table 6). Diets fed to replacement gilts should contain the better-quality grains, free of myco-toxins so that the reproductive tissue will not be affected.

Bone development and mineralization should be increased during the prebreeding period. Higher calcium, phosphorus, copper, and zinc levels should be provided than for market animals. Additional calcium and phosphorus can be stored in bone tissue, and these minerals can be later mobilized if fetal and lactation demands exceed that which is provided in the diet. Insufficient dietary levels of these minerals during the prebreeding period results in bones with low mineral contents with structural weakness. These effects may not become evident until late gestation, lactation, weaning, or during later parities. Consequently, locomotive failure or broken bones can occur in older females, particularly those that were not developed properly as replacement gilts.

A higher intake and body retention of selenium and vitamin E fed to replacement gilts will also be beneficial later in the sow's reproductive life. These latter nutrients also help improve the sow's immune-response and prevent subsequent lactation complications such as mastitis, metritis, and agalactia (MMA).

Acclimation

Replacement gilts are either commonly reared in a grower-finisher facility along with market hogs, or purchased at market weight from a seedstock supplier. It is becoming more common to purchase replacement gilts at 40 to 60 lbs. and then to isolate and allow them to acclimate to herd conditions for several months. By five to six months of age, gilts should be introduced into a gilt replacement pool and fed a diet with a higher nutrient content (Table 6). During the following two- to three-month period, they should be acclimated to the different housing conditions, exposed to sow herd diseases, have fence-line or direct contact with boars, and be monitored daily for estrus activity. Gilts should not be bred until their second or third estrus.

During the period prior to breeding, two feeding strategies have emerged in the United States for replacement gilts.

The first strategy, used largely with maternal lines that are genetically lean, is to increase the gilt's body fat content during the prebreeding period. By feeding a lower protein diet, the rate of muscle growth will be slightly reduced, but there will be an increasing body fat content. Producers with "high-lean" gilts use this method because of the importance of body fat on later lactation and rebreeding performance.

The second strategy, used largely with gilts with less lean potential, invokes the feeding of a lower quantity of a diet during the prebreeding period. This method results in a lower body weight at breeding. Moderate increases in body fatness occur prior to the gilt's initial breeding while maintaining maximum lean. This strategy is used for gilts that have a lower mature body weight than the higher-producing genotypes. If feed is not restricted, many of these gilt lines often get too fat and heavy, which later results in poorer lactation feed intake, less milk production, and lower litter weaning weights. Vitamins and minerals should be formulated at a higher concentration in order to meet the daily quantitative needs of the replacement gilt (Table 8).

When gilts of either strategy are thin at breeding, the provision of a high quantity of feed for 11 to 14 days prebreeding (i.e., flushing) is recommended. Flushing will result in an increased ovulation rate and litter size.

The decision of when to breed gilts is unfortunately often based on the need to fill farrowing groups. Gilt age, weight, and backfat thickness should, however, be the criteria for selecting animals for breeding. Target ages, weights, and backfat thicknesses are presented in Table 7. Research has shown that genotypes with a high-lean and/or high-producing capacity should be bred at heavier body weights than industry average gilts. Breeding gilts after they attain physical and body compositional maturity will help to ensure that they will have sufficient body nutrient stores to meet the metabolic challenges of reproduction. Backfat thickness at the 10th rib may be slightly less than that collected at the last rib.

The influence of gilt age and body condition on their subsequent productivity and longevity depends on several factors including nutrition, feeding management, lactation length, culling criteria, breeding practices, herd health, and housing condition. Allowing gilts to remain in the replacement pool for an extended time can increase production costs and is discouraged. Although the onset of ovulation is largely under genetic control, feeding and management practices can result in gilts being mated by seven months of age without compromising subsequent lifetime performance. The number of estrus cycles should be monitored and daily records kept so that gilts can be bred by their third standing heat or third ovulation. Gilts that do not demonstrate strong estrus behavior should not be bred.

The effective environmental temperatures that gilts are exposed to during the acclimation period is important. The effective environmental temperature is different than air temperature. It is described in practical terms as the temperature that the "animal feels" or its comfort zone. Behavioral characteristics of gilts will generally be a good indicator of environmental conditions that are satisfactory. Drafts of 4 to 10 mph on wet concrete floors can produce an effective environmental temperature that is 7 to 13 degrees colder than air temperature. Conversely, straw bedding and group housing makes pigs "feel" warmer. Increased feed intakes with subsequent decreases in nutrient densities in the diet can be used for colder housing situations (see Table 8).

Table 6. Modified Nutrient Recommendations for Replacement Gilt Development[a].

Item	Weight Range, lb.			
	50-100	100-150	150-200	200-250
Macro-minerals[b]				
Calcium (total), %	0.85	0.80	0.75	0.75
Phosphorus (total), %	0.75	0.70	0.65	0.65
Phosphorus (available), %	0.49	0.45	0.40	0.40
Trace minerals[c]				
Copper, ppm	15	15	15	15
Zinc, ppm	150	150	150	150
Selenium, ppm	0.3	0.3	0.3	0.3
Vitamin E, IU/lb.[c]	20	20	20	30

[a] These nutrients are considered as modifications for replacement gilts. Other nutrient requirements are similar to those in Tables 4 and 5.
[b] Values are total dietary levels unless denoted otherwise.
[c] Values are supplemental levels.

Table 7. Nutrient Recommendations for Replacement Gilts.

Item	High-Producing >250 lb.	Industry Average >250 lb.
	Expected Performance Responses	
Feed intake, lb.	5.5 to 6.5	4.5 to 5.5
Age at breeding, days	210 to 250	210 to 250
Weight at breeding, lb.	270 to 320	240 to 280
Backfat thickness at breeding, inches	0.8 to 1.2	0.8 to 1.2
	Dietary Nutrient Recommendations (As-Fed Basis)	
Protein, %[a]	13 to 14	14 to 16
Amino Acids[a]		
Lysine, %	0.70	0.80
Lysine, g/day	19.10	18.00
Tryptophan, %	0.13	0.12
Threonine, %	0.46	0.50
Methionine + Cystine, %	0.42	0.46
Macro-minerals[a]		
Calcium, %	0.75	0.75
Phosphorus (total), %	0.65	0.65
Phosphorus (available), %	0.40	0.40
Sodium, %	0.20	0.20
Chloride, %	0.16	0.16
(Salt, %)	0.50	0.50
Trace minerals[b]		
Copper, ppm	15	15
Iron, ppm	100	100
Zinc, ppm	150	150
Manganese, ppm	10	10
Iodine, ppm	0.15	0.15
Selenium, ppm	0.30	0.30
Vitamins[b]		
Vitamin A, IU/lb.	2500	2500
Vitamin D_3, IU/lb.	250	250
Vitamin E, IU/lb.	30	30
Vitamin K, mg/lb.	0.50	0.50
Riboflavin, mg/lb.	2	2
Pantothenic acid, mg/lb.	8	8
Niacin, mg/lb.	6	6
Vitamin B_{12}, µg/lb.	8	8
Biotin, mcg/lb.	100	100
Choline, mg/lb.	175	175
Folic acid, mg/lb.	0.75	0.75

[a] Values are total dietary levels unless denoted otherwise.
[b] Values are supplemental levels.

Table 8. Feed Intake and Nutritional Adjustments for Non-Pregnant Gilts Under Cold Stress[a].

Effective Environmental Temperature, °F	Feed intake to meet ME needs, lb.	Percent lysine needed for 12 g/d intake	Percent calcium needed for 16 g/d intake	Percent total phosphorus needed for 14.2 g/d intake	Percent available phosphorus needed for 8.4 g/d intake[b]
65	3.4	0.77	0.98	0.87	0.54
50	4.3	0.61	0.79	0.70	0.43
40	4.9	0.54	0.69	0.62	0.40
30	5.5	0.48	0.62	0.55	0.34
20	6.1	0.43	0.56	0.50	0.30
10	6.4	0.41	0.51	0.46	0.29

[a] Nutrient concentrations needed in final diet when considering change in feed intake. Based on a corn-soybean meal mixture.

[b] Corn-soybean meal diets should be formulated to meet available phosphorus needs of gilts. At feed intakes of 5.5 lb. or greater, formulating on a total phosphorus requirement will not provide enough available phosphorus for animal health and growth.

Questions and Answers for the Replacement Gilt Section

Q. How many estrus cycles should my gilts have before I breed them?

Two to three. This helps avoid lower ovulation rates associated with first ovulations. Physical maturity and body composition should also be considered in gilt selection for breeding. Gilts can be stimulated (boar contact, movement to another building or location, etc.) to encourage estrus onset. Gilts which are not bred by their fourth estrus cycle often go into an anestrus or noncycling condition. Daily monitoring of estrus behavior should be charted for each gilt upon entrance into the breeding pens.

Q. Should I put older sows with my replacement gilts?

This procedure is frequently used to expose incoming gilts to the diseases of the breeding herd, but it also helps in synchronizing estrus among animals. Fence-line contact, rather than mixing in the same pen, prevents possible injury and competition for feed, and still provides the necessary exposure. Because of PRRS and/or other reproductive disease problems, this strategy or its timing should be discussed with your local veterinarian.

Q. What quality of feeds can I feed my replacement gilts?

Diets for gilts and the breeding herd should contain the better quality feed grains, free from spoilage, molds, and mycotoxins. Zearalenone has estrogenic effects that can be detrimental to maximum reproductive efficiency.

Q. Should thin sows be given more feed following breeding?

No. Additional energy after the animal is bred has been associated with increased body heat and higher embryo mortality. After about one month postbreeding, the quantity of feed may be adjusted upward to improve the sow's body condition. The quantity to feed from 30 days post-coitum to farrowing may be as high as 5.5 pounds, but generally ranges from 4.0 to 4.5 lb. per day. Care should be taken to prevent gilts (and sows) from becoming too fat.

The Gestating and Lactating Sow

Pregnancy and lactation are two different processes, but they are physiologically and nutritionally linked. Nutrients supplied during gestation not only affect the development of the litter, but they can also influence the sow's productivity during lactation. A balanced diet fed throughout the reproductive cycle is critical and should contain the better-quality feed grains. The latter is extremely critical as mycotoxins are higher in poorer quality grains. The mycotoxins can result in serious reproductive consequences.

Many high-producing sow lines not only produce more pigs but also produce more milk. Both of these traits result in heavier litter and pig weaning weights. Consequently, differences in sow genotype will directly affect sow nutrient requirements during both reproductive phases. A comparison between the sows of two different productivities is presented in Table 9 and can be used as a guide for your herd. The genetic capability of the sow affects her reproductive performance, but nutritional adequacy during both phases has a direct affect on her longevity in the herd.

The annual culling rate of sows in the United States currently ranges between 30 to 40%, but swine producers should target a goal of retaining at least 75% of the sows for five or more parities. The major reasons for culling sows are:

- Reproductive failure (postweaning anestrus, failure to conceive)
- Poor performance (low litter size, low litter weaning weight)
- Feet and leg problems.

Culling of sows, however, is not only attributable to inadequate nutrition, but also to genotype, facilities, equipment, and management practices. These factors can independently or mutually affect the reproductive performance of the sow herd. Because of the different productivities of parity-one animals compared with older sows, the nutritional recommendations in Tables 10 and 12 allow for these conditions for two different sow genotypes or productivities. Each producer should establish the average lactation feed intake and productive capacity of their sow herd and then provide a diet that will meet the sow's nutrient needs.

Gestation

The diets fed to gilts and sows in the tri-state area are generally a vitamin- and mineral-fortified mixture of corn and soybean meal. Nutrients supplied to the pregnant sow are used for maintenance, body-tissue growth, and for the development of fetal and other reproductive tissues. Protein and energy needs of the fetus increase greatly during the last few weeks of pregnancy.

An adequate body-fat content appears essential for the sow to have several successful reproductive cycles. *The body-fat content of reproducing animals should be closely monitored. Either excessive body condition or low fat reserves can be detrimental to subsequent reproductive performance.* The energy content of the diet and the sow's body-condition score (Figure 7) are the primary factors that determine the quantity of feed that should be provided to the gestating sow (Table 11). High-producing and industry-average genotypes should be bred at a body-condition score of 3.0 (270 to 300 lb. and 240 to 270 lb., respectively).

Older sows, because of their larger size and weight, not only have a higher body maintenance requirement but they often also have a lower body-fat content. Higher productivity during previous reproductive cycles exacerbates the lower body fat content. Because of the wide ranges in productivity and body fat, it is difficult to recommend a specific gestation feed intake for all situations. It is best to use the feeding guidelines in Table 11 and the sow body-condition scores depicted in Figure 7 to determine the quantity of feed to provide for individual sows. A last-rib backfat thickness of 22 to 24 mm (0.90 inch) for parity-one gilts and a backfat thickness of 17 to 19 mm (0.70 inch) when sows reach their fifth parity reflect a body-fat condition that will result in satisfactory reproductive performance.

The quantity of feed to provide gestating animals depends upon the energy content of the diet, sow age, body weight, housing conditions (grouped in pens or individual crates), location of animals such as in complete confinement or in outside lots, and their body condition score as they enter the gestation period. Maternal genotypes that are leaner may need higher feed intakes to sustain an adequate body condition. Attaining an average pig birth weight of 3.0 to 3.2 lb. is a good indicator that the gestation sow feeding program is adequate. There is, however, a tendency in the United States, particularly with parity-one gilts, for them to become too fat by the end of their first gestation period. This condition may have detrimental effects during farrowing, on lactation feed intake, and on subsequent rebreeding performance.

With the higher energy needs of larger litters during late pregnancy, the sow begins to use her body fat reserves during the last few weeks of pregnancy even though she is gaining body weight. Although one may simply increase the sow's feed intake by 1 to 3 lb. during the latter portion of pregnancy (depending upon body fat scores), care should be taken not to allow the sows to become too fat.

There are several methods of feeding gestating sows (once or twice daily, every third day), but feeding once daily in individual stalls or crates is the most popular and will result in reproductive performance that is comparable to feeding twice daily. Feeding sows "every third day" can be satisfactory in outside lots during the warmer seasons and with mature sows, but during colder weather and with first-parity gilts, the results are often less than desirable. Managerial observation of sow health is critical, regardless of feeding method.

Incorporating fat in the gestating sow's diet during the last 10 to 14 days of pregnancy has frequently resulted in improved pig survivability during the first week of life, particularly with litters containing pigs of light birth weights. Supplemental fat provided during the latter portion of gestation has resulted in an increased milk fat content during the subsequent lactation.

Dietary protein (amino acids) concentration is important for the pregnant animal, more so for parity-one gilts who are also developing body muscle along with the fetal and mammary tissue. Older sows in good body condition need less dietary protein (amino acids) for body muscle formation than parity-one gilts.

A 14 to 15% protein diet (i.e., 0.75% lysine) fed to parity-one gilts allows for adequate muscle and fetal development and will be of benefit during the subsequent lactation. A dietary protein concentration of 12 to 13% provided to older high-producing maternal-lean-genotype lines during pregnancy will then be desirable as it will result in an increase in the sow's body-fat content. It is advisable to feed pregnant sows a higher protein diet during the last portion of gestation or no later than when they are transferred to the farrowing crate. The lactation diet can be fed during this period.

Because gestation diets are normally fed once daily in a limited quantity and there are differences in the rate of absorption and utilization of synthetic amino acids (e.g., lysine) compared with the amino acids within the grains or protein source, the use of synthetic lysine in gestation diets is discouraged. Amino acids and starch (glucose) from grains are absorbed more slowly than synthetic lysine, and some of the more rapidly absorbed synthetic lysine is not effectively utilized, whereas lysine from intact protein is more gradually absorbed and better utilized.

Feet and leg problems may be associated with inadequate dietary minerals, particularly calcium and phosphorus, but other minerals and vitamins are also essential for normal development of skeletal and hoof tissue. During the latter portion of gestation, the reproductive demands on the sow for transferring minerals to fetal bone tissue is high. If the sow does not receive adequate dietary calcium and phosphorus, demineralization of her skeleton will occur. The vertebrae and ribs are the bones most vulnerable to the demineralization process if dietary calcium and phosphorus levels are inadequate. This will result in weakened vertebrae. As fetal litter weight increases, displacement of the vertebrae may occur with the spinal cord becoming pinched (Downer Sow Syndrome).

Inadequate biotin has been associated with poor hoof development and cracking of hoof tissue. Because hoof development occurs over a long time, the vitamin should be fortified during the entire weaner-grower period for replacement gilts.

Grains in the tri-state area are generally low in selenium and possibly other trace minerals, particularly copper. Vitamin E is low in high-moisture grains, or grains that are stored for an extended period. Because the grains are inadequate in both nutrients, additional selenium and vitamin E must be fortified in the sow's diet. There is a close relationship between selenium and vitamin E, and both nutrients have also been effective in increasing the immunological capability of the sow. The newborn pig is born with low body reserves of both selenium and vitamin E. When the sow is deficient in vitamin E and selenium, an injection of iron in the newborn pig may cause its death (iron toxicosis). Consequently, gestation diets should be fortified with vitamin E and fortified to the approved concentration of selenium to enhance colostrum and fetal tissue reserves. The dietary levels of other minerals and vitamins in Table 10 are adequate to meet the reproductive needs of gestating sows. The organic form of selenium has been found to be more effective than sodium selenite for reproducing animals.

Lactation

Milk production is largely under genetic control, but can be influenced by environmental and management factors. The selection for high-producing genotypes has resulted in sow lines that produce large quantities of milk. This results in heavier litter and pig weaning weights, with the sows having a high nutrient requirement for lactation. Upon farrowing, the sow largely uses dietary nutrients for the synthesis of milk. If the dietary nutrients are not provided, the body will use tissue reserves in an attempt to meet milk production demands. When this occurs, the breakdown of sow tissue to provide these nutrients will result in a loss of body weight and possibly body function. If excessive, this may result in the premature culling of high-producing sows because of anestrus problems or their subsequent failure to conceive upon weaning.

Sows that are too fat or over-conditioned when they enter the farrowing house (body-condition score 4.5–5) will have a lower feed intake during lactation compared with sows that have lower body-condition scores. Feed intake during lactation is therefore of utmost importance in maintaining high sow-milk production and for successful rebreeding after weaning. *Although sows with a low body-fat content will frequently have a longer weaning-to-breeding interval, a low lactation feed intake is perhaps more responsible for poor breeding performance after weaning than is low body-fat content.* It is essential that feeding practices and farrowing-house conditions allow the sow to consume a high quantity of feed. A high lactation feed intake is needed to maintain high milk production and a minimum loss of body fat. Sows should be brought up to full-feed as quickly as possible after they farrow, but some producers have observed a higher incidence of constipation and mastitis, metritis, and agalactia (MMA) if this is done too rapidly.

It has been demonstrated that sows vary in their desire to consume feed, during the initial week postpartum. Sows that lactate for 14 days or less will have a lower feed intake than those that have a longer lactation period. Consequently, with shorter lactation lengths, the diet needs to be fortified to a higher nutrient content to ensure that milk production demands are met and that the weaning to rebreeding interval is not prolonged. Feed intake will increase each week during a four-week lactation period.

First-parity animals normally consume less feed during lactation than older sows. Because of this, the diet of parity-one sows should be formulated to contain a higher concentration of nutrients.

Most sows will consume from eight to 10 gallons of water per day during lactation. Water flow in the waterer should supply a minimum of 1,500 ml/minute (1.5 quart/min). A separate waterer should be available for the nursing pigs.

The feeding practice for lactating sows that many producers find most helpful is to feed a minimum amount of feed the first day (3 to 5 lbs.) and then to increase that amount by 2 to 3 lb. per day, so that the sow is on full feed by day five of lactation. From this time until weaning, the sow should be fed all she will consume. This assumes that the sow is nursing a litter of nine to 12 pigs.

It is a common practice to feed lactating sows twice a day, but most sows cannot consume enough feed with this feeding practice. The method of feeding lactating sows is critical during the summer months when feed intake is particularly low. The cooler times of the day are generally during the early morning hours. Under these conditions it is important to have an ample quantity of feed in the sow feeder in the evening so that some remains by morning. Therefore, it is wiser to provide feed on a full-feed basis, or to feed a minimum of three times a day. Do not allow the feed to spoil and become moldy in the sow feeder.

Perhaps the limiting factor that restricts feed consumption is the type of feeder used, particularly for mature sows. Because we are now retaining older sows in the herd, their heads are larger and there is a greater difficulty for them to obtain feed from the older-type feeder. New types of sow feeders are now available that allow a full day's feed allotment to be added and have a larger feeding space.

There are several nutritional and management reasons why many sows do not consume an adequate quantity of feed during lactation. These reasons and possible solutions are:

1. Sows are too fat upon entering the farrowing house.
2. The farrowing-house temperature is oftentimes too high. Maintain at 65 – 75°F, and, when necessary, cool the sows.
   - Provide snout coolers.
   - Provide drip coolers (neck and shoulder region).
3. Feeder design is poor.
   - Older sows with large heads cannot consume feed easily in many feeders.
4. Low feeding frequency may cause reduced feed intake.
   - Feed at least three times daily or allow full access to the diet.
5. Use high-quality feed ingredients and freshly mixed diets.
6. Maintain a water flow rate of 1,500 ml/minute (1.5 quart/min).
7. Inadequate ventilation and/or poor air quality will lower feed intake.
8. Poor location of pig heat lamps may cause overheating of sows.
9. Stimulating sows to stand when you enter the farrowing house encourages eating, drinking, and defecation.

The inclusion of fat in the sow's lactation diet has been shown to increase milk-fat content. During the summer months, or when the farrowing house becomes overheated, the addition of fat to the sow's diet may also be of benefit in reducing the body-heat stress and in improving the sow's subsequent rebreeding performance. The inclusion of fat (5 to 10%) in the lactation diet results in a lower amount of heat being released during the digestion process, resulting in lower heat stress on the sow.

The synthesis of milk proteins by the mammary gland is influenced largely by genetics and the dietary amino acid supply. Under conditions when the diet does not provide an adequate quantity of amino acids for milk production, body tissue proteins are selectively broken down, and the released amino acids are used for milk protein synthesis. However, the feeding of a diet low in protein will clearly result in decreased milk production and lower litter weaning weights.

The dietary protein (amino acids) concentration provided to the sow during lactation is of extreme importance in meeting the needs for milk production. The dietary concentration of protein (amino acids) should be adjusted to reflect both the sow's feed intake and milk-production capability. The nutritional requirements of sows of differing productivities for both first and later parities are presented in Table 12. These recommendations reflect normal sow feed intakes during lactation. When other factors lower the sow's feed intake, then the dietary amino acid concentrations need to be adjusted to meet the sow's daily requirements.

In contrast to the gestation period, the lactating sow can more effectively use synthetic lysine if the sow has access to feed continually. Because there is a higher feed intake during lactation, there is a continual absorption of nutrients. This allows for full utilization of absorbed synthetic lysine. When synthetic lysine is used in the lactation diet, care should be taken to ensure that methionine, valine, and threonine are not limiting. If a corn-soybean meal mixture is used and formulated to meet the lysine requirement, there is generally no need to provide additional amino-acid supplementation. If the sow is fed only two times per day, the use of synthetic lysine in the lactation diet is not recommended.

When constipation is a problem, the addition of a fiber source (wheat bran, beef pulp, alfalfa meal) at a 5% level may be helpful. Fiber inclusion in the lactation diet will, however, lower the energy value of the diet. Within a few days of farrowing, the fiber should therefore be withdrawn from the diet and replaced with corn as the sow needs additional energy to sustain high milk production.

Sow milk contains both macro- and microminerals. Calcium and phosphorus are maintained at a relatively constant concentration in sow milk even when the diet provides an inadequate amount. As during late gestation, if an adequate quantity of calcium and phosphorous is not provided in the lactation diet, the sow will demineralize skeletal tissue to meet her needs for milk production. Consequently, high-producing sows and those lactating for a long time are more prone to leg fractures and/or paralysis of the hind quarter (Downer Sow Syndrome). This situation may be worsened upon weaning or when sows are grouped together or mated to a large boar.

Selenium and vitamin E concentrations are lower in the milks of older sows. This situation presents a common problem in the tristate area. Pigs nursing older sows are therefore more prone to the deficiency at birth and after weaning. Because sow body fat contains a large storage of vitamin E, the loss of body fat results in the depletion of vitamin E body stores. Part of the Vitamin E in milk is derived from the body fat as well as from the diet. This condition would have as great an effect on her progeny during the postweaning period as on her own future reproductive performance.

Swine producers should work with their nutritionists (university or feed company) to ensure that the diets for their reproducing animals are adequately fortified to meet the lactation performance of their sow herd.

Weaning to Rebreeding Interval

Upon weaning, there is an immediate reduction in feed intake and body weight as milk production ceases and mammary tissue dehydrates. The sow that is weaned from 17 to 28 days of lactation will normally cycle within five to 10 days of weaning, with longer intervals attributed to parity-one sows and sows that have a poorer body condition. Sows weaned early (i.e., < 14 days) may take an additional two to five days for estrus to occur.

An elevated feed intake from weaning to estrus (flushing) may be beneficial for sows that have lost a great deal of weight and body tissue during lactation. This flushing effect may increase the ovulation rate of poorly conditioned sows. If sows are weaned after 14 days postpartum and are in good body condition, they should be bred on the first cycle postweaning. The gestation diet is a satisfactory feed to provide during this transition rebreeding period. Lactating sows that have lost a great deal of weight and first-parity sows may, in fact, produce larger litters if bred on their second estrus cycle postweaning. The additional feed and facility costs of breeding on the second estrus postweaning need to be considered in this management decision.

Once bred, the sows' feed intake should be immediately returned to the established gestation feed intake level (Table 11). A higher amount of energy consumed during the postbreeding period will cause an increase in body heat, which can affect embryonic mortality.

Table 9. Characteristics of Sow Production Capabilities.

Criteria	Industry Average	High-Producing
Gilt breeding weight, lb.	240–250	280– 300
Pigs born, no.	9 – 11	10 – 14
Pig birth wt., lb.	2.75 – 3.25	2.75 – 3.25
Pigs weaned, no.	7.5 – 9.0	9.0 – 11.0
Pig weaning weight, lb.		
14-day	7.0 – 9.0	9.0 – 11.0
21-day	11.0 – 12.5	12.5 – 14.0
28-day	13.5 – 19.0	16.0 – 18.0
Litter weight (21 day), lb.	90 – 110	130 – 160
Rebreeding interval, day[a]	5 to 10	5 to 10

[a] First-parity rebreeding intervals are generally two to three days longer than for older sows.

Table 10. Nutrient Recommendations for Gestation (Based on Productivity and Age).

Item	Parity 1 Industry Average	Parity 1 High-Producing	Parity 2 and Later Industry Average	Parity 2 and Later High-Producing
		Expected Performance		
Feed intake, lb.[a]	4.0	4.3	4.3 - 5.0	4.6 - 5.5
Feed intake (2 to 3 wk prefarrow), lb.[b]	4.5 - 5.0	5.5 - 6.5	5.4 - 7.0	5.0 - 8.0
Gestation gain (0 – 114 d), lb.	100	125	75 - 100	90 - 110
Gestation gain (0 – farrow), lb.	60	100	50 - 80	60 - 90
Body score at farrowing (0 – 5)	3.5	3.5	3.5	3.5
Backfat thickness (last rib), inch.[c]	0.8 - 1.2	0.8 - 1.0	0.8 - 1.0	0.8 - 1.0
Breeding weight, lb.	240-280	270-320	—	—
		Nutrient Requirements (As-Fed Basis)		
Energy, Mcal ME/lb.	1.4	1.4	1.4	1.4
Protein, %	14	15	12	13
Amino Acids (total)[d]				
Lysine, %	0.65	0.75	0.55	0.60
Tryptophan, %	0.10	0.11	0.08	0.09
Threonine, %	0.42	0.48	0.31	0.36
Methionine + Cystine, %	0.39	0.45	0.32	0.35
Macro-minerals[e]				
Calcium, %	0.90	0.90	0.90	1.00
Phosphorus (total), %	0.70	0.70	0.70	0.80
Phosphorus (available), %	0.42	0.42	0.42	0.45
Sodium, %	0.20	0.20	0.20	0.20
Chloride, %	0.16	0.16	0.16	0.16
(Salt, %)	0.50	0.50	0.50	0.50
Trace-minerals[f]				
Copper, ppm	15	15	15	15
Iodine, ppm	0.15	0.15	0.15	0.15
Iron, ppm	100	100	100	100
Manganese, ppm	10	10	10	10
Selenium, ppm	0.3	0.3	0.3	0.3
Zinc, ppm	150	150	150	150
Vitamins[f]				
Vitamin A, IU/lb.	2,000	2,000	2,000	2,000
Vitamin D, IU/lb.	200	200	200	200
Vitamin E, IU/lb.	30	30	30	30
Vitamin K, mg/lb.	0.50	0.50	0.50	0.50

Continued on next page

Table 10 (continued). Nutrient Recommendations for Gestation.

Item	Parity 1		Parity 2 and Later	
	Industry Average	High-Producing	Industry Average	High-Producing
	Nutrient Requirements (As-Fed Basis)			
Biotin, mg/lb.	0.10	0.10	0.10	0.10
Choline, g/lb.	0.25	0.25	0.25	0.25
Folic acid, mg/lb.	0.75	0.75	0.75	0.75
Niacin, mg/lb.	6	6	6	6
Riboflavin, mg/lb.	2	2	2	2
Pantothenic acid, mg/lb.	8	8	8	8
Vitamin B_{12}, µg/lb.	8	8	8	8

[a] Housing outdoors will increase feed (energy) intake requirements. The intake values presented in this table reflect feeding once daily under indoor conditions in individual feeding stalls.
[b] The quantity to be provided will depend upon sow body-fat score. For scores less than 3.5, feed at the upper level; whereas if the body fat score is > 4.0, the lower levels should be fed.
[c] Measurements at the end of gestation. If backfat thickness is measured at the 10th rib, the value will be about 10% higher.
[d] Total amino acid recommendations reflect a diet composed of a corn-soybean meal mixture. The amino acids listed are those that are commonly limiting.
[e] Values reflect total dietary concentration, unless noted otherwise.
[f] Values reflect the supplemental level to be added to the diet.

Table 11. Estimated Feed Intakes for Gestating Sows Fed a Corn-Soybean Meal Diet[a].

Parity	Gestation Weight Gain (lb.)	Farrow Weight[b] (lb.)	Body Condition Score (1-5)	Backfat (last rib)[c] Inch	Backfat (last rib)[c] mm	Approximate Feed Intake, lb.[d] Industry Average	Approximate Feed Intake, lb.[d] High-Producing
1	90-125	350-400	3	0.8 – 1.0	20 – 25	4.0	4.3
2	70-100	380-425	3	0.8 – 1.0	20 – 25	4.3	4.6
3	70-100	420-450	3	0.8 – 0.9	19 – 21	4.5	4.9
4	70-90	450-480	3	0.7 – 0.8	18 – 20	4.8	5.2
5–7	70-90	480-520	3	0.7 – 0.8	18 – 20	5.0	5.5

[a] Based upon herd measurement averages, the daily feed intakes should be adjusted to match the housing environment and the sow's body score.
[b] Farrowing weight will reflect the initial breeding weight plus gestation gain. Lean-maternal genotypes may be bred at a heavier body weight without becoming fat.
[c] Collected upon entrance to the farrowing house.
[d] Estimated gestation feed intakes to achieve the desired measurements. Adjustments may be needed based on body conditioning score.

Table 12. Nutrient Recommendations for Lactation (Based on Productivity and Age).

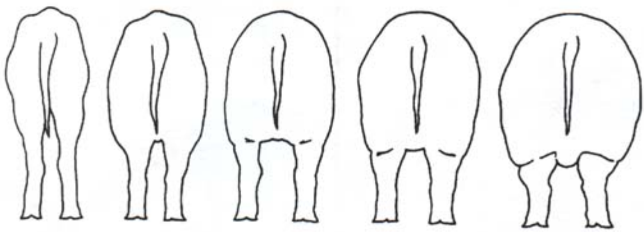
Item	Parity 1		Parity 2 and Later	
	Industry Average	High-Producing	Industry Average	High-Producing
	Expected Performance			
Daily feed intake, lb.				
0–14 day	8.5 – 10.0	9.5 – 10.5	10.5 – 12.0	11.5 – 14.0
0–21 day	9.5 – 10.5	10.0 – 11.0	11.0 – 13.0	12.5 – 16.0
Lysine intake/day, g	35	43	38	50
Lactation weight loss (Farrow-Weaning), lb.	10 – 20	15 – 25	0 – 15	0 - 20
Rebreeding interval, days	7 to 12	7 to 12	4 to 7	4 to 7
	Nutrient Requirements (As-Fed Basis)			
Energy, Mcal ME/lb.	1.5	1.5	1.5	1.5
Protein, %	15	18	14	16
Amino Acids (total)[a]				
Lysine, %	0.75	0.90	0.70	0.80
Tryptophan, %	0.15	0.18	0.13	0.15
Threonine, %	0.50	0.55	0.47	0.53
Methionine + Cystine, %	0.45	0.47	0.40	0.45
Valine, %	0.75	0.90	0.70	0.80
Macro-minerals[b]				
Calcium, %	0.90	1.00	0.90	1.00
Phosphorus (total), %	0.70	0.80	0.70	0.80
Phosphorus (available), %	0.42	0.45	0.42	0.45
Sodium, %	0.20	0.20	0.20	0.20
Chloride, %	0.16	0.16	0.16	0.16
(Salt, %)	0.50	0.50	0.50	0.50
Trace-minerals[c]				
Copper, ppm	15	15	15	15
Iodine, ppm	0.15	0.15	0.15	0.15
Iron, ppm	100	100	100	100
Manganese, ppm	10	10	10	10
Selenium, ppm	0.3	0.3	0.3	0.3
Zinc, ppm	150	150	150	150
Vitamins[c]				
Vitamin A, IU/lb.	2,000	2,000	2,000	2,000
Vitamin D, IU/lb.	200	200	200	200
Vitamin E, IU/lb.	30	30	30	30
Vitamin K, mg/lb.	0.5	0.5	0.5	0.5
Biotin, mg/lb.	0.10	0.10	0.10	0.10
Choline, g/lb.	0.25	0.25	0.25	0.25
Folic acid, mg/lb.	0.75	0.75	0.75	0.75
Niacin, mg/lb.	6	6	6	6
Riboflavin, mg/lb.	2	2	2	2
Pantothenic acid, mg/lb.	8	8	8	8
Vitamin B_{12}, µg/lb.	8	8	8	8

Continued on the next page

Table 12 (continued). Nutrient Recommendations for Lactation.

[a] Total amino-acid content reflects a diet compound largely of a corn-soybean meal mixture.
[b] Values reflect total dietary concentrations unless noted otherwise.
[c] Values reflect the supplemental level to be added to the diet.

Figure 7. Body Condition Scores Used for Sows (Late Gestation).



Score	Condition	Backfat (last rib) inch	Backfat (last rib) mm	Body Characteristics
1	Emaciated	< 0.4	< 10	Hips, backbone, ribs prominent to the eye.
2	Thin	0.4 - 0.6	10-15	Hips, backbone, and ribs are easily felt without applying palm pressure.
3	Ideal	0.7 - 0.9	15 - 22	Hips, backbone felt only with firm palm pressure, ribs easily felt but covered.
4	Fat	1.0 - 1.1	23 - 29	Hips, backbone, and ribs cannot be felt easily.
5	Overfat	> 1.2	> 30	Hips, backbone, and ribs heavily covered.

Questions and Answers for the Gestating and Lactating Sow Section

Q. How early in lactation is milk production set?

The first 48 hours post farrowing will generally establish the milk production and mammary-secretory capability of the sow. Unused glands will become nonfunctional within a few days post farrowing. This is the major reason for performing cross-fostering of pigs early in lactation.

Q. How can sow lactation feed intake be determined?

One way is to weigh out a certain quantity of feed (e.g., 100 lb.) for each sow and then determine how many days that quantity of feed will last. Divide the amount of feed used by the number of days to establish daily feed intake. An alterative method is to record the number of feed containers (weigh scoops, coffee cans, etc.) used to feed the sows over a period of several days and determine the average amount consumed per day. Because sows differ in their ability to adjust to feed post farrowing, it may be best to determine feed consumption after four or five days post farrowing.

Q. Is it necessary to adjust the dietary lysine level in my sow herd when I am getting low feed intakes?

Yes. Lysine is generally the amino acid most likely to limit milk production in the lactating sow when a corn-soybean meal diet is fed. A low feed intake will result in a low lysine intake. It is essential to formulate lactation diets to a lysine concentration that reflects the feed intake of the sow herd. This process is important for first-parity sows and during the hot months of the year when feed intake is low.

Q. Is there a benefit in feeding higher dietary protein/lysine during lactation to my parity-one sows?

Yes. Large lactation weight losses and low feed intakes followed by poor rebreeding performance are common occurrences, particularly with first-litter sows. A limited amount of research suggests that the feeding of a lactation diet with a lysine level above 1.00% may be beneficial in eliminating some of these adverse effects in first-parity sows.

Q. How much lysine is required for the lactating sow?

Sows weaning eight pigs or less require from 35 to 40 grams of lysine per day, whereas those sows that wean 10 pigs or more may require 50 grams per day.

Q. Is there any value in adding valine to lactating-sow diets?

No. Some experiments have demonstrated a response to added synthetic valine (essential amino acid) to sow diets but most have not. When synthetic lysine is used in the lactation diet and replaces soybean meal, the concentration of other amino acids (e.g., valine) may be reduced below the sow's requirement. In contrast, if soybean meal is used as the sole supplemental protein source, there will be no benefit to added valine.

Q. How much supplemental fat should I add to my gestation and lactation diets?

Adding fat to sow diets at a moderate level (3 to 5%) has not affected sow lactation feed intake, nor has it been shown to affect sow lactation weight loss. Levels of 8 to 10% added fat have resulted in reduced sow-feed intakes. The addition of 3 to 5% fat to the lactation diet has, however, been shown to increase milk-fat content and will generally result in larger litter weaning weights. When fat is added at dietary levels above 5%, the bridging of feed in the sow feeder may become a problem. Generally, supplemental fat is not recommended during gestation unless it is fed to thin sows during the latter portion of pregnancy.

Q. My sows appear constipated during late gestation and the first few days post farrowing. Is this normal? How should I prevent this?

Dehydration is common following the farrowing process because the sow has lost body water from the expulsion of birth products. It takes a few days for a sow to recover from the farrowing process and to return to a normal water balance. In general, if a sow consumes an adequate quantity of water and feed during the first few days post farrowing, the remaining portion of the lactation period is considered to be relatively safe from constipation problems. If constipation persists, laxatives or a diet containing a higher fiber level (e.g., wheat bran) can be fed during late gestation and early lactation.

Q. Can a sow that has just weaned her litter be used as a foster mother for lightweight pigs?

Yes. Under proper management conditions and assuming the nurse sow has adequate body condition to nurse for an additional few days, the sow has successfully nursed the adopted litter. This procedure can be effective when pigs are batch weaned, but not when the all-in, all-out weaning practice is followed. Care should be taken to ensure that the transfer of pigs is successful. Allow the milk supply to build up in the sow's mammary glands for a few hours and then permit the sow to nurse the litter immediately upon transfer. This will result in a more successful transition.

Q. Is split-weaning helpful?

Under conditions where you want the lighterweight pigs to be heavier at weaning, the removal of the heavier pigs (allowing the lightweight pigs to remain nursing the sow) will give good results. Lightweight pigs will benefit from a few extra days of nursing the sow. If the sow nurses at least five pigs, she will not come into estrus while nursing.

The Boar

Interest in feeding boars to optimize semen quality and quantity and retaining the boar in the herd for a longer time have received increased attention in recent years. However, scientific research regarding the nutrition of the boar is lacking. Therefore, many feeding strategies used by commercial and private boar studs are based on a minimal amount of boar research. Experience and research that has been conducted with grower-finisher pigs is generally used to establish most nutritional requirements. Our estimates of the nutrient requirements for the growing and mature boar are presented in Table 13.

Developing Boars

The number of muscle cells in the adult boar is established at birth with postnatal muscle growth involving an increase in their size (hypertrophy). Hence, different feeding strategies or nutrient supplies to the young boar will not alter the number of muscle cells of the young animal nor will it affect what he transmits genetically. Because muscle is the largest body component in the growing boar, growth of muscle mass generally parallels the growth of the whole animal. Improvements in daily gain, feed efficiency, loin-eye area, and lower backfats occur when boars are provided the dietary protein concentration that meets their requirement.

The boar's retention in the herd is largely dependent on the size and the subsequent maintenance of its skeleton. This is largely influenced by genetics, but it is also dependent upon a sound nutritional program during the boar's developmental period. Structural soundness at sexual maturation is essential for optimum breeding performance and subsequent semen production. Grouping young boars during the pre-pubertal developmental period results in fewer feet and leg problems and has also been shown to improve sexual behavior.

Although bone structure is an inherited trait, adequate dietary macro- and micromineral concentrations must be provided for proper bone development. Boars have bones of a greater length and diameter than either gilts or barrows. An increased dietary calcium and phosphorous concentration is therefore necessary for the higher bone mass and bone-mineral content, both of which are essential in withstanding breeding stresses on the legs. An adequate dietary vitamin D concentration will ensure optimum absorption and utilization of calcium and phosphorus. However, an excessive amount of vitamin D may cause calcification of connective tissue and decalcification of bone tissue.

Sexual maturation in the boar is a gradual process, with sexual activity and sperm production starting at approximately four months of age. Testosterone concentration in the blood increases by five to seven months, with "sexual maturity" occurring at six to eight months of age. Semen collected as early as five months of age is at a low volume and contains a high proportion of immature and abnormal sperm. Therefore, the use of boars for breeding should not be initiated too early.

When feed is restricted to the boar prior to puberty, both growth rate and sexual maturity will be delayed without permanently damaging the testes. The seminiferous tubules in the testes, which are the origin of the sperm cells, however, will be reduced in diameter and size.

The practice of restricting boar feed intake during late development to maintain a lower breeding weight has several risks. If the intake of the nutrients is below the boar's requirement, semen quality and quantity may be affected, with bone structure and health compromised. This could result in poor reproductive performance and the premature culling of the animal. The diet must be fortified to supply the required nutrients (Table 13). Because weight, age, body condition, and collection frequency can affect the amount of feed that should be provided, feed intake recommendations are presented in Table 14.

Mature Boars

As the boar matures, semen volume and sperm numbers increase. Larger testes produce more sperm, and if boars are fed insufficient energy, testes size will be reduced. If protein intake is low, boar libido, semen volume, and sperm output will also be reduced.

Sow gestation diets are generally satisfactory for meeting the needs of the mature boar. An additional amount of feed (i.e., energy) must, however, be provided to maintain the boar, particularly during the winter months in cold housing environments. Inadequate feed consumption will result in a low energy intake and can affect semen production.

Mature skeletal size in the boar is reached at approximately one to two years of age. Maintaining structural soundness in mature boars is critical, particularly in pen mating conditions. If the boar is fed a diet inadequate in calcium and phosphorous, the bone structure will continue to grow, but the bones will not mineralize properly, and weakened bones and joints may occur. It is therefore essential that an adequate concentration of dietary vitamins and minerals be provided when the boar is fed a restricted quantity of feed. Boars used in pen-mating situations need to be heavier than boars used for hand mating or for artificial insemination. Boars used for pen mating also need to be heavier than the females they are to breed. The behavioral interactions of animals within the pen increases the rigors of mating and the potential number of leg and foot problems that can occur.

Semen Collection

Routine semen collection of boars at three- to four-day intervals initially at 6.5 to 7.0 months of age seems to have no effect on the development of the testes, accessory sex glands, or subsequent semen characteristics. By 10 months of age, the volume of ejaculate is reduced when daily collections are compared to three-day collections. Although there is a reduced sperm concentration in the daily ejaculations, total weekly numbers of sperm are only slightly increased from daily vs. three-day collections. Increased boar usage generally does not result in increased sperm production.

The impact of different feeding strategies on sperm numbers and viability has not been fully investigated. Nutrients that may be required in greater amounts with higher producing animals and those under heat stress are vitamin E, vitamin C, zinc, selenium, manganese, and copper.

Table 13. Nutrient Recommendations for Boars (As-Fed Basis).

	Development Phase			
Item	Early[a]	Middle[a]	Late[b]	Mature[b]
Body weight, lb.	50-120	120-200	200-300	300-600
Protein, %	22	20	18	16
Amino acids[c]				
Lysine, %	1.2	1.1	1.0	0.85
Tryptophan, %	0.24	0.22	0.19	0.17
Threonine, %	0.86	0.79	0.68	0.58
Methionine + Cystine, %	0.72	0.66	0.63	0.54
Macro-minerals[c]				
Calcium, %	0.95	0.85	0.80	0.90
Phosphorus (total), %	0.75	0.65	0.75	0.80
Phosphorus (available), %	0.49	0.40	0.49	0.50
Sodium, %	0.12	0.12	0.20	0.20
Chloride, %	0.08	0.08	0.16	0.16
(Salt, %)	0.25	0.25	0.50	0.50
Trace-minerals[d]				
Copper, ppm	15	15	15	25
Iodine, ppm	0.15	0.15	0.15	0.15
Iron, ppm	100	75	75	100
Manganese, ppm	10	10	10	20
Selenium, ppm	0.3	0.3	0.3	0.3
Zinc, ppm	150	100	100	150
Vitamins[d]				
Vitamin A, IU/lb.	2500	2000	2000	2500
Vitamin D, IU/lb.	250	200	200	250
Vitamin E, IU/lb.	30	30	30	30
Vitamin K, mg/lb.	0.6	0.6	0.6	1.0
Biotin, mg/lb.	0.10	0.10	0.10	0.10
Choline, g/lb.	0.25	0.25	0.25	0.60
Niacin, mg/lb.	15	12	12	15
Riboflavin, mg/lb.	6	4.5	4.5	6
Pantothenic acid, mg/lb.	10	7.5	7.5	10
Vitamin B_{12}, µg/lb.	15	15	15	20

[a] Assumes *ad libitum* feeding.
[b] Assumes limit feeding.
[c] Values reflect total dietary concentrations unless noted otherwise.
[d] Values reflect the supplemental level to be added to the diet.

Table 14. Feeding Guidelines for Boars.

Body Wt. (lb.)	Pounds of Feed for Maintenance[a]	Target Gain/Day (lb.)	Pounds of Feed for Gain[b]	Total Feed/Day (lb.)[cd]
300	3.42	1.2	1.50	4.9
350	3.78	1.1	1.38	5.2
400	4.14	1.0	1.25	5.4
450	4.47	0.9	1.13	5.6
500	4.80	0.8	1.00	5.8
550	5.11	0.7	0.88	6.0
600	5.42	0.6	0.75	6.2
650	5.71	0.5	0.63	6.3
700	6.00	0.4	0.50	6.5

[a] Based on a corn/soybean meal diet.
[b] Assumes 80% efficiency.
[c] Add 0.25 lb. feed/ejaculate.
[d] Add 0.1 lb. feed for each degree temperature below 68°F.

Questions and Answers for the Boar Section

Q. Should my boars gain weight while in the breeding herd?

Yes. Boars need to gain at an appropriate rate until they reach maturity. Overfeeding boars at any age is an unwise practice as it will affect their breeding performance and libido. Underfeeding boars can lower the quantity and quality of semen, result in lameness, ulcers, and poor health conditions.

Q. Should I feed antibiotics to my boars?

Antibiotics can be fed to boars but should be fed a low dietary level. Therapeutic concentrations should not be fed unless recommended by a veterinarian.

Q. What specific nutrients are boars more likely to require during heavy usage?

During periods of heavy breeding, the quantity of energy and protein may need to be increased. Selenium has also been shown to be important for sperm development and maturation. Vitamin C has also been shown to improve semen quality when boars are heat stressed.

Q. Should boars be fed prior to or after being used for breeding?

Our recommendation is to feed boars prior to breeding or semen collection.

Q. How can I prevent leg problems in my boars?

Selection of boars with initially correct skeletal structure will help to ensure their longevity. Feeding appropriate diets for the age, use, and size of the boar is essential. Calcium, phosphorus, magnesium, zinc, copper, and biotin are nutrients that are required to ensure proper bone and foot development and maintenance.

Feed Ingredients

Feed grains only meet part of the nutrients that are required in the diets of pigs. Therefore, other feed components are needed to balance the diet. Combining the grains and other ingredients into a final diet mixture to meet the pig's nutritional needs requires information about the nutrient content of each feed grain, knowledge about their nutritional limitations, and the suggested feeding level. Variations in crop growing conditions, storage length, and crop variety may produce wide compositional variations among and within individual grains. Average compositional values of commonly used feeds are presented in Table 15 and can to be used as a guide in formulating diets for swine. Suggested incorporation rates of various grains and by-products are presented in Table 16, with the composition of commonly used mineral sources listed in Table 2.

Test weight is perhaps the quality attribute of grains that can best reflect their overall nutritional value. Although most of the test-weight variation is due to the starch component, it is a general reflection of growing conditions and nutrient content of the grain. Common test-weights are normally expressed in the United States as lb./bushel [corn (56), oats (32), sorghum (56), wheat (60), and barley (48)]. Grains having lower test weights than that indicated in the parentheses contain more fiber, less starch, and have a lower digestible energy value than normal test-weight grains. The percentage of crude protein of low test-weight grains may, in fact, be higher than that of the normal test weight. This is because in low test-weight grains, the starch content is reduced and the protein is, therefore, at a higher proportion to the other components. Low test-weight grains usually result from early frost conditions, a situation that also encourages the development of mycotoxins. Pig growth rate is usually not affected until test weight is extremely low. Feed conversions are generally poorer due to the grain's higher fiber content. Poorer performance responses noticeably occur when test weights (lb./bushel) are between 70 to 80% of normal. Because of potential differences in test weights, volumetric feed mills should be calibrated frequently to assure that the diet contains the correct proportion of feed components.

Dietary fats and oils contain 2.25 times more energy than carbohydrates (starch). This means that 1 lb. of fat added to a diet will be approximately equivalent to the energy present in 2.25 lb. of corn starch. The addition of fat to a diet thus results in improved feed conversion because the diet contains a more concentrated form of energy. Although the addition of fat to market pig diets improves feed conversion, body-fat deposition is often increased, particularly in barrows during the latter stages of the finisher period.

Choice white grease and soybean oil are considered higher-quality fats compared to yellow grease. Many of the fat products commercially available for feeding pigs are blends of various animal and vegetable sources. Several contain high amounts of free fatty acids and other impurities that reduce their quality. High-quality animal fat sources and animal-vegetable fat blends should contain no more than 1% moisture, 0.5% impurities, 3.5% unsaponifiable material, or 5% total MIU (moisture, impurities, and unsaponifiable material). The presence of water in a fat mixture can accelerate equipment deterioration and/or the development of rancidity in either the stored fat or in the final diet mixture. Diets that contain rancid products will result in a low feed acceptability that subsequently reduces pig gains and feed conversion ratios. Antioxidants such as ethoxyquin, butylated hydroxyanisole (BHA), or butylated hydroxytoluene (BHT) are generally added to fat sources to prevent the development of rancidity.

The most common and cheapest energy source for pig diets in the tri-state area is yellow dent corn, but other grains and by-products are also available and are often economical. It is essential that an analysis of the grain or feed product be conducted prior to feeding to ascertain its nutrient composition and quality. Analyses for moisture, protein (and possibly lysine) and test weight are generally adequate for grains. Suggested incorporation rates of various grains and by-products are presented in Table 16.

In addition to regular yellow dent corn, several new varieties of corn (high-oil, high-lysine, low-phytic acid) have or will become available in the near future. The varieties of high-oil corn have a 6 to 9% oil content and a lysine content of 0.28 to 0.30%, whereas regular yellow dent corn averages 3.5% oil and 0.25% lysine. The germ component of the high-oil corn kernel, which is proportionally higher than in regular corn, accounts for most of the additional oil and lysine. Consequently, an increased digestible energy content of about 5% and a 7% improvement in feed conversion is frequently reported when feeding trials have compared these high-oil corn varieties with regular corn.

The high-lysine corn varieties generally have a higher but also a wider variation in their lysine content than regular corn. The use of high-lysine corns generally does not result in improved pig gains but can result in a lower feed cost. When high-lysine corn is fed, there should be a reduction in the dietary level of supplemented protein and/or synthetic lysine added per ton. The total dietary lysine level should be the same for both types of diets.

Much of the phosphorus in the cereal grains and soybean meal is bound with phytic acid and is poorly digested by the pig. Consequently, a large quantity of phosphorus is excreted in swine manure. Low phytic-acid corn varieties have about 35% of their phosphorus bound in phytic acid compared to 70% for regular corn. The newer varieties of low-phytate corns allow for more phosphorus to be in an inorganic form; thus, the phosphorus in these corns is more effectively digested and absorbed by the pig with less being excreted.

Soybean meal is the most economical and commonly used swine protein (amino acid) supplement used in the tri-state area. Although soybean meal quality can be variable and its protein (amino acid) content can be influenced by crop growing conditions, it generally has a more consistent quality than most other protein sources used for swine diets. Dehulled 48% crude protein (CP) soybean meal is the processed meal without the soybean hulls being added back to the meal, whereas 44% CP soybean meal has the soybean hulls returned to the meal after the oil has been extracted. The 44% CP soybean meal has a fiber content of 7.5%, compared to the 3.5% fiber in dehulled soybean meal. The decision to use 44 or 48% crude protein soybean meal should be based on the cost per unit of protein, not on the price per ton. Both sources of soybean meal have the same proportion of the amino acids, but differ in the total percentage of amino acids (as fed basis). Table 16 shows recommended usage rates of various protein sources normally used in pig diets.

Whole (full-fat) soybeans are frequently used to increase the energy content of swine diets. The use of roasted or extruded full-fat soybeans generally adds 3 to 4% oil to the final diet mixture (the diet normally contains from 2 to 3% oil from the cereal grain contribution).

Due to the oil in the whole soybean, the intact bean has a lower protein and lysine content. Consequently, a higher level of the whole bean must be included in the diet compared to diets that have soybean meal as the protein supplement. Because of the presence of several anti-nutritional factors in raw whole soybeans, the bean must be heat-processed by being roasted or extruded prior to being used in swine diets. Many extruders and roasters can produce an excellent full-fat soybean product, but there is a wide variation in the technical ability of equipment operators to produce a quality product. Economic analyses have generally not favored on-farm roasting or the extruding of soybeans. With the higher oil content in the final diet mixture, feed intake will be slightly lower when the roasted whole soybean is added. Raw soybeans containing mycotoxins should be avoided and not fed to swine, particularly to young pigs and reproducing animals.

There are many grain and industry by-products that can be used in pig diets. Commonly used plant by-products include corn gluten meal, corn gluten feed, hominy feed, brewers products, distillers dried grains, and various mill feeds such as wheat, bran, shorts, and middlings. Animal by-products would include meat and bone meal, blood meal, fish meals, milk products, and various animal fats. These by-products have varying nutrient compositions, but each has a nutritional limitation. Some of these by-products are valuable protein or amino acid supplements, whereas others are good energy sources (Table 15).

Table 15. Composition of Commonly Used Feed Ingredients in Swine Diets (As-Fed Basis).

Item	Digestible Energy[a]	Crude Protein	Lysine	Methionine	Met + Cys	Threonine	Tryptophan	Ether Extract	Crude Fiber	Calcium	Phosphorous	
											Total	Available
	(Mcal/lb.)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Energy Sources												
Alfalfa meal, dehydrated	830	17.0	0.74	0.25	0.43	0.70	0.24	2.6	41.2	1.53	0.26	0.26
Bakery waste, dehydrated	1787	10.8	0.27	0.18	0.41	0.33	0.10	11.7	2.0	0.13	0.25	—
Barley	1383	10.5	0.36	0.17	0.37	0.34	0.13	1.9	18.6	0.06	0.36	0.11
Beet pulp	1300	8.6	0.52	0.07	0.13	0.38	0.10	0.8	42.4	0.70	0.10	—
Corn, high lysine	1600	9.0	0.35	0.20	0.40	0.36	0.12	3.6	9.6	0.03	0.28	0.04
Corn, high oil	1675	8.1	0.32	0.20	0.40	0.30	0.08	7.0	9.6	0.03	0.28	0.04
Corn, yellow	1600	8.3	0.26	0.17	0.36	0.29	0.06	3.9	9.6	0.03	0.28	0.04
Fats/oils												
Animal-poultry, fat	3865											
Corn oil	3971											
Lard	3758											
Soybean oil	3969											
Beef Tallow	3629											
Millet, pro80	1370	11.1	0.23	0.31	0.49	0.40	0.16	3.5	13.8	0.03	0.31	—
Millet, pearl	1320	11.8	0.35	0.23	0.46	0.42	0.09	6.7	13.8	0.03	0.32	—
Molasses, beet	1140	6.6	—	—	0.12	—	—	—	—	0.03	—	—
Molasses, cane	1000	4.4	—	—	—	—	—	—	—	0.77	0.08	—
Oats	1256	11.5	0.40	0.22	0.58	0.44	0.14	4.7	27.0	0.07	0.31	0.07
Oat groats	1673	13.9	0.48	0.20	0.42	0.44	0.18	6.2	—	0.08	0.41	0.05
Rye	1484	71.8	0.38	0.17	0.36	0.32	0.12	1.6	12.3	0.06	0.32	—
Sorghum, grain	1533	9.2	0.22	0.17	0.34	0.31	0.10	2.9	18.0	0.03	0.29	0.06
Triticale	1505	12.5	0.39	0.20	0.46	0.36	0.14	1.8	12.7	0.05	0.33	0.15
Wheat bran	1098	15.7	0.64	0.25	0.58	0.52	0.22	4.0	42.1	0.16	1.20	0.35
Wheat, soft red winter	1564	11.5	0.38	0.22	0.49	0.39	0.26	1.9	—	0.04	0.39	0.19
Wheat middlings	1395	15.9	0.57	0.26	0.58	0.51	0.20	4.2	35.6	0.12	0.93	0.38
Whey, dried	1512	12.1	0.90	0.17	0.42	0.72	0.18	0.9	—	0.75	0.72	0.70
Amino Acid Sources												
DL-Methionine	—	58.7	—	99	99	—	—					
L-Lysine · HCl	—	95.8	78	—	—	—	—					
L-Threonine	—	73.5	—	—	—	99	—					
L-Tryptophan	—	85.7	—	—	—	—	98					
Protein (Amino Acids) Sources												
Blood meal, flash-dried	1043	87.6	7.56	0.95	2.15	4.07	1.06	1.6	—	0.21	0.21	—
Blood meal, spray-dried	939	88.8	7.45	0.99	2.03	3.78	1.48	1.3	—	0.15	1.71	—
Canola meal	1308	35.6	2.08	0.91	2.34	1.59	0.45	3.5	21.2	0.63	1.01	0.21
Corn gluten meal, 60%	1916	60.2	1.02	1.09	2.52	2.08	0.31	2.9	8.7	0.05	0.44	0.07
Fish meal, menheden	1710	62.3	4.81	1.77	2.34	2.64	0.60	9.4	—	0.21	3.04	2.85
Meat and bone meal, 50%	1106	51.5	2.51	0.68	1.18	1.59	0.28	10.9	32.5	9.99	4.98	4.48
Meat meal, 55%	1222	54.0	3.07	0.80	1.40	1.97	0.35	12.0	31.6	7.69	3.88	—
Plasma proteins, spray-dried	1529	78.0	6.84	0.75	3.38	4.72	1.36	0.2	—	0.15	1.71	—
Skim milk, dried	1805	34.6	2.86	0.90	1.22	1.62	0.51	0.9	—	1.30	1.00	0.91
Soy protein concentrate	1860	64.0	4.20	1.90	1.90	2.80	0.90	0.6	—	0.35	0.81	—
Soybeans, full-fat, cooked	1877	35.2	2.22	0.53	1.08	1.41	0.48	18.0	13.9	0.25	0.59	—
Soybean meal, 48%	1671	47.5	3.02	0.67	1.41	1.85	0.65	3.0	8.9	0.34	0.69	0.16
Soybean meal, 44%	1583	43.8	2.83	0.61	1.31	1.73	0.61	1.5	13.3	0.32	0.65	0.20
Sunflower meal	1288	42.2	1.20	0.82	1.48	1.33	0.44	2.9	27.8	0.37	1.01	—

[a] To convert digestible energy values to metabolizable energy, multiply by 0.96.

Table 16. Suggested Maximum Incorporation Rates of Feedstuffs in Swine Diets.

Ingredient	Maximum Recommended Percent of Complete Diet				Nutritional or Dietary Limitation
	Starter	Grow-Finish	Gestation	Lactation	
Alfalfa meal, dehy	0	10	25	0	High fiber
Bakery waste, dehy	25	20	10	10	High salt
Barley	15	40	40	25	High fiber
Beet pulp	0	5	50	10	High fiber
Blood meal, spray-dried	3	5	5	5	Low isoleucine/ Acceptability
Canola meal	0	15	15	15	Anti-nutrition factor
Corn	60	80	90	80	Lysine
Corn distillers grains w/solubles, dehy	5	15	40	10	Amino acid balance
Corn gluten feed	5	10	15	5	High fiber
Cottonseed meal	0	10	15	0	Lysine/Gossypol/fiber
Egg protein, spray-dried	6	10	10	5	Anti-nutrition factor
Fat/oils	8	5	5	5	Feed handling
Fish meal	20	6	6	6	"Fishy" pork
Hominy feed	0	60	60	60	Amino acid balance
Meat and bone meal	5	5	10	5	High minerals
Meat meal	0	5	10	5	High minerals
Millet	10	40	40	20	Hard seed coat
Molasses	0	5	10	5	Energy/Handling
Oats	5	20	50	0	High fiber
Oats groats	10	0	0	0	Expensive
Porcine plasma, spray-dried	10	0	0	0	Expensive
Rye	0	25	25	10	Variability/Ergot
Skim milk, spray-dried	30	0	0	0	Expensive
Sorghum (milo)	40	80	90	80	Lysine
Soy protein concentrate	20	0	0	0	Expensive
Soy protein isolate	10	0	0	0	Expensive
Soybean meal	15	25	15	20	Antigenic factors
Soybean, full-fat, heat-treated	0	20	10	10	Overheating
Sunflower meal	0	20	10	0	Lysine/Fiber
Tankage	5	5	5	5	Quality variable
Triticale	10	40	40	40	Variable quality/Ergot
Wheat bran	0	10	30	10	High fiber
Wheat	0	40	30	40	Expensive
Wheat middlings	5	25	25	10	High fiber
Wheat shorts	10	40	40	40	Variable quality
Whey, dried	40	15	5	5	Expensive
Yeast, brewers dried	5	10	10	10	Variable quality

Questions and Answers for the Feed Ingredient Section

Q. What cereal grains other than corn, wheat, oats, milo, or barley may be available?

There are small acreages of buckwheat, millet, and spelt grown in the tri-state area. All of these grains can be used in pig diets, but care should be taken to balance the diet for amino acids. Their compositions and their individual specific nutritional limitations (e.g., lysine, fiber, etc.) will determine their dietary incorporation level.

Q. How much wheat can I use in pig diets?

Normally, only about 50% of the grain mixture should be comprised of wheat, largely because the product is generally too fine and becomes unacceptable. If the particle size is between 600 to 800 microns (each kernel broken into four to six pieces), wheat can be used to replace all of the corn.

Q. What guidelines should be measured in soybean meal to ensure receiving a good quality product?

Soybean meal must be heated to reduce the various antinutritional factors indigenous in soybeans, but the meal product should not appear burnt. Color, crude protein, and fiber levels are good indicators of quality meal and can be evaluated at most feed-testing laboratories. Frequently, ground limestone is added to processed soybean meal to improve its flowability. You should request guaranteed compositional information when purchasing soybean meal in bulk quantities, and retain a sample of the product upon delivery.

Q. How can I effectively add fat in my on-farm mixer?

Fat must be in a liquid form and be the last item added to the feed mixture in the mixing process. Unless a tank is available for the storage and heating of fat, most producers are not in a position to add fat to their swine diets. The use of dry fats can be added to feed mixers, but these fats are generally too expensive unless used for specialized use. When commercial feed is normally pelleted, fat is generally sprayed onto the pellet as it exits the die. As the pellet cools, the fat is absorbed within the pellet. Regardless of the method of adding fat, be sure to consider that the cost of energy from fat should not exceed 2.25 times the price of corn.

Feed Additives

Feed additives are not nutrients nor are they required in the diets of animals. They often, however, result in improved animal growth rates, feed conversions, and are generally profitable when fed correctly. Some feed additives are regulated by the U.S. Food and Drug Administration (FDA), and it is crucial that regulations regarding their use and inclusion level be closely followed. The regulations are published annually in the Feed Additive Compendium. Appropriate usage and withdrawal (if necessary) information for each additive can be obtained from the manufacturer and/or from the feed tag affixed to commercial feeds.

There are various groupings of feed additives, which include:

1. Antibiotics and antimicrobial agents
2. Growth and feed efficiency enhancers
3 Beta-adrenergic agonists
4 Mold inhibitors and preservatives
5. Flavoring agents
6. Microbial cultures
7. Enzymes
8. Anthelmintics (dewormers)

Antibiotics and Antimicrobial Agents

These compounds, when added to swine diets at low dietary levels, have been shown to improve animal growth, feed conversion, and reproductive performance. At high (therapeutic) concentrations, these agents are used to cure or prevent specific diseases or disease conditions. For either situation, they should only be used at the dietary concentration and/or only in combinations approved by FDA.

Nursery pigs almost always exhibit a beneficial response to dietary antibiotic inclusion, resulting in improved gains and feed conversions within a range of 5 to 15%. The response is generally higher (10 to 15%) when pigs are housed on solid floors and bedding. With pigs that are reared in raised decks or under more sanitary conditions, the performance benefits are somewhat lower (6 to 10%). Growing pigs (40 to 150 lbs.) also exhibit a growth response to antibiotics (4 to 6%), but the response declines (0 to 4%) as the pig reaches market weight.

Pigs, which are in a very high-health status and/or are placed in new freshly cleaned facilities with excellent management practices, generally respond less to antibiotic inclusion, particularly after they become adjusted to new facilities.

There are two main points of concern when antibiotics are fed to livestock:

- Withdrawal time, if any, must be adhered to because of the potential antibiotic residue that may remain in the animal's tissues.
- Microorganisms sometimes develop resistance to antibiotics, making the antibiotic less effective over time.

Although bacterial resistance can develop to some antibiotics, use of dietary antibiotics continues to be effective in enhancing pig growth and feed-conversion responses. The best advice is to use the antimicrobial products sparingly and in accordance with FDA regulations.

To ensure that pork producers use antibiotics correctly in their swine herds, the National Pork Producers Council has established a Pork Quality Assurance (PQA) program on residue avoidance. This program effectively acquaints producers with different drugs, their level of inclusion, approved combinations, and proper withdrawal times. The FDA's Compliance Policy Guide (CPG 7125.37, Proper Drug Use and Residue Avoidance by Nonveterinarians) outlines the producer's responsibilities when using animal health-care products. The producer must:

- Identify and track animals to which drugs were administered.
- Maintain medication and treatment records identifying: the animals treated; the date(s) of treatment; the drug(s) administered; who administered the drug(s); the amount administered; the withdrawal time prior to slaughter.
- Store, label, and account for all drug products and medicated feeds properly.
- Use only veterinary prescription drugs obtained through a licensed veterinarian based on a valid veterinarian/client/patient relationship.
- Educate all employees and family members involved in treating, hauling, and selling the animals on proper administration techniques; observe withdrawal times; and observe methods to avoid the marketing of adulterated products for human food.

Regulations for distributing new feed medications have recently changed, and details of the regulations are still being developed. The Veterinary Feed Directive (VFD) category of feed, established by Congress as part of the Animal Drug Availability Act (1996), provides a method of distributing new therapeutic drugs in a manner that assures veterinary supervision without making them prescription products. Swine producers should become aware of the new regulations through their feed suppliers, veterinarians, and State Extension specialists.

Copper Sulfate

Copper sulfate ($CuSO_4 \bullet 5\,H_2O$) has a copper content of 25% and has frequently been used at high levels (125 to 250 ppm Cu) to attain a growth response in weanling and market pigs. The 250 ppm level corresponds to 0.1% copper sulfate in the final diet mixture, which is equivalent to 2 pounds per ton of diet. Although the addition of copper sulfate to swine diets is legal, care should be taken to assure an even distribution of copper in the diet mixture. A dietary copper level of 500 ppm is toxic to swine. An added benefit is often obtained when antibiotics and copper sulfate are used in combination for growth promotion, particularly for weanling pigs.

Zinc Oxide

Zinc oxide is added to many nursery diets at levels between 2,000 and 3,000 ppm. Zinc has been shown to improve starter pig growth rate. The form of zinc should be zinc oxide, as other inorganic forms of zinc have not resulted in the same response. The product should not be fed for more than four weeks.

Acidifiers

Adding organic acids (fumaric, propionic, citric) to nursery diets has been shown to improve daily gain and feed conversion responses during the early nursery period. Dietary acid inclusion may be particularly beneficial when there is a problem with *E. coli* in the nursery. Acidic conditions in the stomach and intestinal tract from organic acid inclusion are not conducive to *E. coli* growth.

Acids can also be used as a preservative for high-moisture grain (stored grain and final diet mixture), where the acid acts as a mold-growth inhibitor. Acids frequently used are acetic, fumaric, propionic, and their salts. It is important to remember that these acids may be somewhat dangerous to handle and caustic to metal equipment and flooring.

Chromium Picolinate

Chromium supplementation (0.2 ppm or 200 ppb) to swine diets has been approved by FDA and has been reported to enhance carcass leanness in barrows, but the research data are not consistent. Limited data have also indicated that chromium picolinate increases the number of pigs born live and increases sow conception rates. Chromium is considered an essential nutrient, but because the requirement is considered so low, it may not be deficient in most swine diets. No deficiency symptoms have been described in pigs. Chromium may participate in carbohydrate metabolism by enhancing the effects of the hormone insulin. Inorganic chromium is ineffective in the diets of swine, whereas other organic chromium forms have not been approved by FDA.

Betaine

Betaine has been reported to increase carcass leanness and to enhance swine feed efficiency. Recent research has failed to support this claim. Those trials where betaine has been shown to be effective may have been related to an amino acid (methionine, cystine) deficiency.

Carnitine

Carnitine functions within the cell to transport lipids into the mitochondria to enhance their use as an energy source. Young mammals do not have the ability to synthesize an adequate amount of carnitine from lysine. Carnitine has been shown to reduce backfat thickness in finishing pigs.

Beta Agonists or Repartitioning Agents

Beta agonists are frequently called "repartitioning agents," as they divert dietary energy for body muscle formation instead of fat. Consequently, pigs fed repartitioning agents are leaner and have more muscle mass and less body fat. Although several compounds are being investigated, none are currently approved by FDA.

Counteracting Mycotoxins and Mold-Inhibiting Agents

Grains can develop molds that produce mycotoxin compounds either prior to harvest or while in storage. High-moisture conditions enhance the development of mycotoxin production. Vomitoxin (DON) appears to be the main problem, whereas in the tri-state area, aflatoxin is not a major problem. Mold inhibitors can be added to feeds to avoid the development of mycotoxin production. Certain mycotoxins can be partially detoxified by a variety of procedures, including ammoniation and heat treatment. Decontamination methods for grains in commercial use are regulated and require government approval. Hydrated sodium calcium aluminosilicate and bentonite have also been used and often result in improved animal performance. These products reportedly bind aflatoxin in the feed or intestinal tract, therefore decreasing their absorption from the digestive tract. These products, however, do not effectively bind all mycotoxins.

Feed Flavors, Chocolate, or Special Feeds That Pigs Prefer

When pigs are given the choice of several diets, they will show a preference for substances that are sweet. However, when not given a choice, they usually eat the same amount of feed whether or not it contains the sweeter ingredients. Flavors have been used in specialty feeds to simulate milk or to enhance feed intake in starter diets. Some chocolate by-products are used in nursery diets.

Yucca Plant Extract

Extracts from the desert cactus plant, *Yucca schidigera*, have resulted in increased feed efficiency in pigs. The active components in this plant have also been shown to reduce ammonia production in swine buildings and have been used in odor control.

Microbial Cultures

The general concept behind adding live microbial cultures (probiotics, etc.) is that the organisms will populate the intestine with "good bacteria," and through competition inhibit the growth of "bad" pathogenic bacteria. However, there is little scientific research to support these claims, and their addition to swine diets is questionable.

Enzymes

Several enzymes are currently being added to feeds. The addition of protein-digesting enzymes has not shown much improvement in pig growth rate, but some of the newer products have shown promise. A few carbohydrate-digesting enzymes may be beneficial in some circumstances, especially in those diets containing barley and wheat. The enzymes ß-gluconase and cellulase have increased the digestion of complex carbohydrate.

Phytase

A high proportion (55 to 80%) of the phosphorus in cereal grains and oilseed meals is bound chemically in the form of phytate. The phosphorus in this form is poorly digested by pigs because they lack the enzyme (phytase) needed to remove phosphorus from the phytate molecule. Because of this, an "available" inorganic phosphorus source must be added to the diet to meet the pig's requirement for this nutrient.

Adding the enzyme phytase to the pig's diet has been shown to be an effective means of increasing the phosphorus availability from the phytate molecule in the digestive tract. When this enzyme is added, a lower dietary phosphorus concentration can be fed. Studies have indicated that the inclusion of phytase in swine diets has increased the availability of phytate phosphorus in a corn-soybean meal diet from 15% to 45% and has increased some of the trace minerals. Phytase is approved by FDA and is available in a form that can be added to swine diets.

The inclusion of the phytase enzyme in the diet will reduce the amount of phosphorus excreted in the feces. The 30 to 35% reduction in excreted phosphorus is important because environmental regulations have been proposed that will regulate swine waste application.

Laxatives in Sow Diets

Constipation of sows during late gestation or within a few days of farrowing is commonly encountered. Although a slight dehydration is normal for sows giving birth, sows may temporarily show signs of constipation. This condition is generally of a short duration. In many cases, constipated sows had not received adequate water. Sows that are group housed during gestation generally have fewer constipation problems than sows housed in individual stalls because they have been more physically active. Laxatives can improve sow bowel movements and subsequent lactation feed intake.

Both mineral laxatives and/or the addition of fiber to sow diets are methods that have been used to control constipation in adult sows. The addition of either minerals or fibrous feedstuffs during gestation will generally result in satisfactory results.

Anthelmintics (Dewormers)

Pigs are susceptible to both internal and external parasites, and appropriate measures to control these parasites are available and should be used. Internal parasites compete directly for the nutrients in the digestive tract, thereby decreasing pig growth rate which also increases the feed conversion ratio. Internal parasites may migrate through the body and damage the internal tissues, reducing their functionality and making pigs susceptible to other diseases.

Methods to control both internal and external parasites are available. Good management practices and appropriate use of anthelmintic products need to be followed to have an effective parasite control program. Anthelmintics can either be in an injectable or feed-additive form. The most common time to administer dewormers for reproducing animals is prior to breeding and before farrowing. Young pigs should be dewormed one to two weeks postweaning and again three to six weeks later to remove the adult parasites that were eggs at the first deworming. The specific use and timing of anthelmintics should be administered according to label directions and under the guidance of a veterinarian. Approved products are presented in Table 17. A routine slaughter check of market animals will verify the effectiveness of the program being followed.

Organic Selenium (Yeast)

Grains contain a natural source of organic selenium, but the grains grown in the tri-state area have a low selenium content. Although inorganic selenium (sodium selenite) is approved by FDA and is routinely added to most swine diets at 0.3 ppm, research has shown that about 60% of it is excreted in the urine. Organic selenium (yeast) is an effective source of selenium; is more effectively retained in muscle, milk, and fetal tissues than inorganic selenium; and less is excreted. Currently, the organic yeast product is not approved by FDA.

Questions and Answers for the Feed Additive Section

Q. Should the dietary calcium level be adjusted when using phytase?

Yes. The total Ca:P ratio can be maintained at approximately 1.1:1 when phytase is added. The normal Ca:P ratio is 1.2:1 to 1.5:1.

Q. What other minerals are made more available from phytase addition?

Zinc, copper, iron, magnesium, and calcium are also bound within the phytate molecule and are released when phytase is used in the diet.

Q. What are the recommended levels of mineral laxatives?

Potassium chloride is generally added at a level of 12–15 lb./ton.

Magnesium sulfate is added at a level of 2–10 lb./ton.

Table 17. Approved Anthelmintics for Pigs.[a,b]

Parasite	Dichlorvos	Fenbendazole	Levamisole	Ivermectin	Pyrantel Tartrate	Piperazine	Thiabendazole
Roundworm *(Ascaris suum)*	✓	✓**	✓	✓	✓***	✓	
Nodular worms *(Oseophagostomum spp.)*	✓	✓	✓	✓	✓	✓	
Whipworm *(Trichuris suis)*	✓	✓**					
Lung worms *(Metastrongylus spp.)*		✓	✓	✓			
Red stomach worm *(Hyostrongylus rubidus)*		✓		✓			
Threadworm *(Strongyloides ransomi)*			✓	✓			✓
Kidney worm *(Stephanurus dentatus)*		✓**	✓	✓**			

a A ✓ indicates that the product removes 90% of adult worms.
b Hygromycin is not included since it is a feed additive used as a prophylactic.

** Also effective against immature stages.
*** Prevents ascarid larval migration by killing the larvae as they hatch from ingested embryonated eggs.

Feed Processing

Cereal grains are processed (cracking, grinding, rolling, extruding, expanding, etc.) only in order to improve their nutritional and economic value. Grinding or cracking cereal grains improves the utilization of nutrients primarily through improved digestibility by producing smaller particle sizes. Heating by expanding or extruding can also reduce the antinutritional factors, particularly those that are present in oilseed products. Because most feeds and grains are normally processed in some manner, the methods of processing and handling feed products prior to and during the mixing process are critical in order to maximize the economic return to the swine enterprise.

Particle Size

Reduction of whole grain to a smaller particle size will improve feed efficiency. By reducing particle size, the surface area is increased. This allows the particle surface to have greater contact with digestive enzymes in the intestinal tract. When particle size is reduced from 1,000 microns to 400 microns, digestibility is increased by an average of 5 to 6%. The average particle size of most ground feeds is approximately 1,100 microns, whereas the desired size to attain optimum digestibility is between 650 and 750 microns. Reducing particle size below 650 microns increases digestibility but it also increases the cost of grinding and reduces the output of the mill (Table 18). The excretion of undigested nutrients is therefore reduced when the particle size is smaller. Segregation or the separation of feed ingredients can also be minimized by grinding the grain to the same particle size as that of the protein source (approximately 700–750 microns). Incidences of stomach ulcers are, however, higher when feed is ground too fine. Management problems can occur when feeding diets that are too finely ground (e.g., bridging).

Hammer Mill versus Roller Mill

The grinding or rolling of grain can produce acceptable swine feeds if the mills are operated correctly. However, there are differences between these two types of mills in their processing capacities. Roller mills can process twice the amount of product as a hammer mill. Roller mills can also produce uniform particle sizes, which can result in improved digestibility. However, roller mills require more upkeep to maintain the correct setting on the roller gaps, whereas hammer mills require less monitoring. Roller mills have a greater difficulty in processing small grain seeds to the correct particle size, and those grains that have a hard seed coat (e.g., sorghum) should always be ground.

Hammer mills have an advantage in flexibility of use. Because of their pulverizing nature, hammer mills can effectively process high-fiber feed components at a more uniform particle size.

Pelleting

Pelleting a diet is an effective way to improve feed conversion for all phases of swine production, particularly when grains or byproducts have a higher fiber content. The pelleting of corn-soybean meal diets will not generally result in improved performance or feed conversion, whereas the pelleting of high-fiber diets almost always improves pig gain and feed conversion.

During the starter phase, a small increase in feed intake may be observed when the diet is pelleted. A 4 to 6% improvement in feed conversion is generally obtained when diets are pelleted compared with those fed in meal form. Improved feed conversion is attributable to at least two factors. First, there is a reduction in feed wastage; second, there is an improvement in the digestibility of nutrients. The latter is largely due to the fine grinding of the grain prior to pelleting and the use of steam heat, which is commonly used during the pelleting process. Steam heat expands the starch molecule, which increases its surface area which enhances digestive enzyme contact. A side benefit to pelleting is a 10 to 20% reduction in nutrient excretion which results from reduced feed wastage and improved feed conversions.

Mixing

Mixing times that are necessary to process diets will vary with the type of mixer, the relative capacity of the load within the mixer, and the maintenance condition of the mixing equipment. A feed mixture is acceptable when the variation between several samples is less than 10%. (Samples for analyses can be collected at periodic intervals as the mixer is emptied.) Horizontal mixers will generally reach the 10% variation standard within three to four minutes after the final component is added, whereas the single-screw vertical mixer generally requires eight to 12 minutes. If the mixer has a large amount of wear on its ribbons or screws, or if the mixer is filled above its rated capacity, the variation may be higher (20 to 30%). There is a direct relationship between the RPM of the mixer and the time required to mix a diet. The faster the RPMs, the sooner will the 10% variation be achieved.

The proper sequencing of feed ingredients into the mixer helps in manufacturing diets of good and uniform quality. A suggested mixing procedure is:

1. Add 30 to 40% of the grain.
2. Add the vitamin and trace mineral premixes (and other ingredients that have a low inclusion rate).
3. Add protein source(s).
4. Add remaining grain.
5. Mix.
6. Add supplemental liquids and fat sources.
7. Mix for the final time.

Diets should be mixed in a sequence that prevents drug residue problems. This process is termed "batching." *To avoid drug residue problems with market animals, never mix the finishing diet immediately after a medicated feed (e.g., starter pig diet).* Drug residue can be a problem with many on-farm mixers where 20 to 30 lbs. of residual feed often remains in the bottom of the mixer after the feed is discharged. This residue is often the source of most contamination problems between feed mixes. Removal of the clean-out plate and the residual feed after every medicated diet is mixed is essential in preventing the carry over of drugs to the next diet mixed. Many exit ports on feed mixers are not easily accessible, so the problem can be minimized by mixing diets in a correct batching sequence. This procedure uses the principle of mixing feeds that contain potential residue problems followed by diets that will be fed to animals not intended for market at least in the near future.

Vitamin Stability — Mixing Vitamins and Trace Minerals

Although various feed grains and by-products contain natural vitamins, many are destroyed when the kernel is damaged or consequently cracked. Purchasing a properly fortified vitamin premix is only part of the job in providing the correct nutrition to the pig. Vitamin stability within the premix and after the diet is mixed varies greatly between vitamins. This is largely dependent on the various conditions of where and how the vitamin premix is stored. Moisture, heat, and the contact of vitamins with trace minerals are the most common reasons why vitamin stability is reduced. Choline chloride is hygroscopic, and when added to a vitamin premix it will generally hasten the rate of other vitamin destruction. Vitamin premixes should be stored in a cool, dark, dry location. Storage length of vitamin premixes should not exceed three months. The more stable vitamins have potency losses of less than 1% per month. The less stable vitamins may have losses of 4 to 6% per month but could be as high as 15 to 30%, particularly when mixed with trace minerals. Pelleting will cause vitamin destruction with stable vitamins having losses of 2 to 6% per month, while less stable vitamins lose 10 to 25% of their activity.

Grain Storage

Because cereal grains make up 40 to 85% of most swine diets, their quality is critical. Good grain storage starts with high-quality grain obtained at harvest. There are steps that swine producers can take to ensure properly stored grain. Harvested grains should be dried to 13 to 14% moisture when stored. Grain-drying temperatures should not exceed 180°F as a higher heat may result in a lowered lysine availability and an increase in the amount of cracked grain. Dried grain needs to be cooled before being stored. As grain enters the cooling bin, the removal of fines improves grain quality. Fines are often the cause of spoilage and molds. Producers should determine the temperatures in the top foot of grain in the bin to make sure that the cooling fans have adequately cooled the grain. Once grain is cooled, seal the air duct of the grain bin to prevent temperature fluctuations. These practices will help in preventing hot spots within the grain bin. An ideal grain-storage temperature is between 30 to 35°F. Temperatures of 60°F or higher result in mold development and insect activity. This can be caused by changing weather conditions, or from the warming of the grain during the subsequent spring and summer. Sealing the bin also helps to prevent an increase in the rodent population.

Storage and Mixing of Fat

Fat is often added to swine diets not only as a source of energy but also as an effective way of reducing the amount of dust in swine buildings. On-farm feed mixers can incorporate fat in either a liquid or dry form. Larger amounts (>7%) of fat in the diet may, however, prevent feed from flowing freely in storage bins and feeders, thus causing "bridging" in feeders.

Fat can rapidly become rancid when using feed-grade oils/fats if the fat is not protected from oxidation. Antioxidants added to the fat at the time of storage prevent the occurrence of rancidity. Routinely adding an antioxidant to all fat/oil sources upon their arrival is a good management practice. Another approach is to be sure that it was added when processed at the rendering plant.

The addition of fat to the mixer should be during the last part of the mixing process so that it can be rapidly incorporated and prevented from covering the sides of the mixer. It is best to mix the diet for a few minutes and then add the fat during the last two to three minutes of mixing.

Questions and Answers for the Feed Processing Section

Q. Do I need to do my own quality control on feed ingredients?

If you are purchasing large quantities of ingredients or even if you use custom premixes, it would be advisable to save samples for possible analysis. Each ingredient should be sampled upon delivery and be retained in a cool, dry location in an airtight container. If a problem arises, then the samples can be analyzed.

Q. How do I take a feed sample to assure that I get a good analysis?

For each batch of feed or for each ingredient, several (3 to 10) evenly distributed samples should be collected and mixed thoroughly. A one-pound subsample can be stored and submitted for analysis. Store the sample in an airtight container in a cool, dry location.

Q. What analysis should I have done on my grains and feeds?

Grains should be analyzed for test weight, moisture, and protein upon harvest. A mycotoxin analysis should be conducted if a problem is suspected. Protein sources should be analyzed for protein, calcium, and phosphorus. A lysine analysis is desirable.

Q. Where can I get my feed analyzed?

There are several laboratories that do feed analyses. Contact your State Extension specialist for a current listing of laboratories in your area.

Q. What amount of analytical variation should I expect from a laboratory analysis?

An acceptable variation for most nutrients should be within 8 to 10% of the calculated value.

Q. I have read that limestone is added to soybean meal to improve its flowability. Is this true, and what should I do?

Yes, limestone and/or other materials are frequently added to soybean meal to improve its flowability. If limestone is used, the calcium content of the bean meal would affect how much additional dietary calcium would be needed in the final diet. Request from the manufacturer the compositional information on the product purchased.

Q. Does particle size of limestone affect pig performance?

Yes. Large particles of limestone will result in reduced digestibility and poor distribution in the mix. If the particle size for limestone is too fine, there may be a chemical binding of the calcium to other minerals in the digestive tract, which also lowers its availability. Dolomitic limestone contains magnesium, and there is a reduced availability of calcium from this limestone source.

Q. What is an "open" and a "closed" formula?

An open formula lists the percentage or amount per ton of all ingredients in the complete feed, premixes, or supplements. A closed formula does not identify precise concentrations of the feed ingredients, but lists the ingredients used for the formulation. Most commercial feeds use a closed-formula concept.

Table 18. Effect of Grain Particle Size on Mill Energy Costs and Mill Production Capacity.

	Grain Particle Size, Microns			
Item	1000	800	600	400
Milling energy, kilowatt hours/ton	2.42	2.78	3.46	7.35
Milling production, tons/hr	3*	3	2.85	1.43

* Milling production was limited by capacity of exit auger.

Mycotoxins

Several mycotoxins are reported to be present in grains and in stored feedstuffs, but only five have been shown to cause much difficulty with swine in the United States. Those mycotoxins, their causative organism, and their most important effects are discussed and presented (Table 19).

The most serious mycotoxin threat to swine is from **aflatoxin.** This mycotoxin is not generally present in the feed grains grown in the tri-state area, but is common in feeds from the South. Aflatoxin is produced by the common soil microorganism *Aspergillus flavus* and is a major problem in peanuts and their by-product feeds. Aflatoxin can, however, occur in corn and other grains when growing conditions are hot and dry. Aflatoxin is a toxic product, causing liver damage, reduced growth, and feed conversion at levels above 100 ppb. It can be carcinogenic, and FDA regulates the maximum dietary level at 20 ppb.

Deoxynivalenol (DON) is often called vomitoxin because of its strong emetic effect on the animal. Because of the very strong feed refusal response which DON elicits, pigs are seldom seen vomiting. The pig seems to be more sensitive to the presence of this mycotoxin in feed than other livestock species. Starvation is the condition usually observed. Poor performance associated with poor feed intake occurs above a dietary level of 1 ppm.

Zearalenone is produced by the same organism as DON but usually is formed under different conditions. The two metabolites (DON, zearalenone) may therefore be found together or separately in feeds. Zearalenone consumption will produce vulva swelling, prolapse, pseudopregnancy, false heat symptoms, and other estrogenic problems in the reproductive process. The organism that produces DON and zearalenone has been a source of confusion in taxonomy, and its name and classification have been changed more than once. *Fusarium roseum* is now the accepted name, but a particular stage of the organism, *Gibberella zeae*, produces the toxins and has been used by many to avoid some of the confusion with other terms. It is from this latter name of the organism that the term "Gib corn" originates.

Fumonisin is a recently discovered mycotoxin that is extremely toxic to horses and often is fatal. It can affect swine, causing pulmonary edema and liver damage. The organism producing this mycotoxin, *Fusarium moniliforme*, is a very common organism often present with no production of fumonisin. There is limited evidence regarding toxic levels, but dietary concentrations below 10 ppm appear to be without discernible effect in swine.

Ergot is a parasitic fungus of the *Claviceps* genus. *Claviceps purpurea* grows mainly on rye, wheat, triticale, and barley. Rye and triticale seem to be most susceptible. The fungus replaces the seed in the heads of these cereal grains and produces several (four primary) **alkaloids** that are toxic to pigs and most other animals. This mycotoxin (alkaloids) causes vasoconstriction of blood vessels and eventually gangrene of the limbs. Ergot-infested grain should **never** be fed to pregnant animals and should be used sparingly in grower/finisher pig diets.

Table 19. Feed Mycotoxins of Importance to Swine.

Mycotoxin	Causative Organism	Primary Effect
Aflatoxin	*Aspergillus flavus*	Decreased production, liver toxicity, death, carcinogenic
Deoxynivalenol (DON); also called vomitoxin	*Fusarium roseum* (or, *Gibberella zeae)*	Feed refusal
Zearalenone	*Fusarium roseum* (or, *Gibberella zeae)*	Estrogenic-like reproductive upsets
Fumonisin	*Fusarium moniliforme*	Pulmonary edema
Ergot and Alkaloids	*Claviceps purpurea*	Vasoconstriction, dry gangrene of the extremities

Table 20. Maximum Allowable Levels of Mycotoxins in Swine Diets.

Production Phase	Aflatoxin (ppb)	Deoxynivalenol (ppm)	Zearalenone (ppm)	Fumonisin (ppm)	Ergot and Alkaloids (%)
Breeding Herd	100	1.0	2.0	2–5	0.10
Nursery Pigs	20	1.0	1.0	2–5	0.10
Grower Pigs	50–100	1.0	1.0	2–5	0.10
Finisher pigs	200	1.0	3.0	2–5	0.10
Boars	100	1.0	3.0	2–5	0.10

Questions and Answers for the Mycotoxin Section

Q. Will mycotoxins be a problem in grain by-products?

Grain screenings are a potential source of mycotoxins. Grain found in the bottom of storage bins is often contaminated with mycotoxins.

Q. Where can I get a mycotoxin analysis?

Animal Disease Diagnostic Laboratory, Purdue University, West Lafayette, IN 47907

Contact your Extension specialist for recognized laboratories within your state.

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