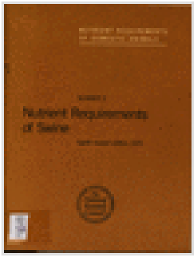

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

Increasing demands upon agricultural production necessitate continued greater efficiency of animal production. Changes in breeding and management, and the introduction of new feedstuffs and methods of feed processing influence nutrient metabolism and requirements; hence, there is a continuing need for reevaluation. Because of the variety of factors that influence requirements, the quantitation of nutrient requirements is a complex area. This report reflects the increased knowledge and improved methodology in the establishment of nutrient requirements for swine during various stages of the life cycle.

This Eighth Revised Edition of *Nutrient Requirements of Swine* has been prepared by the Subcommittee on Swine Nutrition, Committee on Animal Nutrition, Board on Agriculture and Renewable Resources, Commission on Natural Resources of the National Research Council.

Changes from the previous edition and some consideration in applying the information contained herein include:

1. Modification of recommended requirements reflects new information.
2. Since the outward signs of many nutrient deficiencies are similar, pictures of animals meant to depict signs of simple nutrient deficiency have been omitted.
3. Tables of nutrient requirements have been expanded to include trace elements and requirements for a live weight range of 1 to 5 kg.
4. The availability of nutrients in ingredients used in swine diets is known to vary. Many of the requirements listed are based upon the feeding of corn-soybean meal diets and should not be considered as absolute values. In formulating diets, the relative availability of nutrients must be considered, especially when the main ingredients are not corn and soybean meal. No margin of safety for such variation has been included.
5. Nutrient requirements and feed composition data are expressed on an air-dry basis (90 percent dry matter).
6. A table of common mineral sources for swine has been included.
7. All data are presented in the metric system with tables of equivalents and conversion factors shown.
8. Feed ingredients are identified by International Feed Numbers adopted by the Committee on Animal Nutrition (United States) and the National Committee on Animal Nutrition (Canada).
9. For more detailed information on nutrients and research related to requirements, pertinent literature citations are listed in the Bibliography.

Grateful appreciation is expressed to members of the Committee on Animal Nutrition (United States), the National Committee on Animal Nutrition (Canada), and others who provided information and suggestions. The subcommittee is also indebted to Philip Ross, Executive Secretary, and Selma P. Baron, Staff Associate, of the Board on Agriculture and Renewable Resources, for their assistance in the production of this report, and to A. I. Aydin, Joseph H. Conrad, Tony J. Cunha, George K. Davis and Ernest R. Peo, Jr., for their comprehensive reviews and constructive comments on the report.

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INTRODUCTION

Water, energy, protein, vitamins, and minerals must be provided in the correct amounts and proportions if optimum results are to be obtained in the support of maintenance, normal growth, and reproduction in swine.

Although the exact quantitative need for each nutrient is not known, the most reliable estimates of requirements have been compiled and are presented in Tables 5–8. Requirements, as presented, should be considered as minimum requirements and do not include a margin of safety. The recommendations are based upon the assumption that diets will contain about 90 percent dry matter. Where values from several comparable experiments were available for consideration, the approximate average of those values was used. References to corn–soybean meal or grain–soybean meal diets refer to vitamin and mineral fortified diets of this general composition. It can be assumed that recommendations will also apply following the inclusion of most other energy- and protein-furnishing ingredients.

It is known that breed, strain, and sex affect growth rate, feed conversion, and carcass composition, and, therefore, these factors influence nutrient requirements. The required dietary level will also be influenced by:

1. Feed intake
2. Energy density of the diet
3. Level and interaction of nutrients in the diet
4. Availability of nutrients to the animal
5. Presence and level of feed additives
6. Environmental temperature, housing conditions, and level of subclinical disease
7. Presence of toxins, inhibitors, or molds in the diet
8. Expected level of performance and carcass composition.

NUTRIENT REQUIREMENTS

Carbohydrates, lipids, proteins, minerals, vitamins, and water are the six classes of nutrients required for maintenance, growth, and reproduction of swine. Each nutrient has specific functions and, in addition, carbohydrates, lipids, and proteins are used to supply the energy requirements of animals, but with different levels of efficiency.

ENERGY

In nearly all conditions under which swine are fed, carbohydrates and lipids supply most of the energy needs of the body. These energy requirements are expressed as kilocalories of digestible energy or metabolizable energy needed per kilogram of feed (Tables 5 and 7) and per animal per day (Tables 6 and 8). Digestible energy (DE) is defined as the dietary gross energy intake minus the gross energy excreted in the feces. Metabolizable energy (ME) is defined as the gross energy of the diet minus fecal and urinary gross energy. The loss of energy as gas produced in the digestive tract of nonruminants is usually small and therefore the ME values for swine are not corrected for energy lost through the gaseous products of digestion.

The ME value of a feedstuff, diet concentration, or daily allowance can be estimated from the DE value using the formula from Asplund and Harris (1969):

$$\text{ME} = \text{DE} \times \left[\frac{96 - (0.202 \times \text{crude protein \%})}{100}\right].$$

The ME content of ingredients used in swine diets generally comprises 90 to 97 percent of DE. A more precise estimate of ME can be obtained by correcting ME for nitrogen gained or lost from the body (ME_n). For the pig, a correction factor of 7.0 kcal/g nitrogen is used for each gram of nitrogen above or below nitrogen equilibrium. This correction is added to the ME for animals in negative nitrogen balance and subtracted when the pig is in positive nitrogen balance.

Net energy is used to describe the energy utilized by the animal. A portion of the ME is used for conversion or metabolism of absorbed dietary components into tissue and is defined as heat increment (HI). Thus, net energy (NE) may be defined as ME less the heat increment. Net energy is used by the animal to meet the requirement for maintenance (NE_m) and for production (NE_p). In the growing pig the efficiency of utilization of NE required for maintenance and production is similar; thus the two components are seldom separated.

Net energy, as a fraction of ME, has been shown to vary from 27.2 percent for wheat middlings to 69.0 percent for corn. It has therefore been suggested that NE, though difficult to measure, may be the best measure of the energy available for the maintenance and production of an animal. However, energy utilization is influenced by the level of feed intake; the balance of all the nutrients in the diet; the age, breed, sex, and condition of the animal used in the determination; and the environmental conditions that are present during the determination. At present, NE requirements for maintenance and production are not available, and, therefore, the energy requirements of swine (Tables 5–8) and the energy values of the feedstuffs commonly used for swine (Table 9) are presented as DE and ME values.

Because the amount of feed consumed daily by growing–finishing pigs fed *ad libitum* is to a large extent controlled by the energy content of the diet, it follows that the other nutrients are required in some specific ratio to energy. Energy consumed in excess of that required for maintenance, increase of lean body mass, or reproduction leads to deposition of body lipid. Therefore, the lean-to-fat ratio of the pig may be altered by controlling the daily energy intake. The potential for such fat deposition is greatest as the pig approaches maturity. If pregnant sows are fed a corn–soybean meal diet, or another palatable diet of similar energy content, *ad libitum*, they consume more energy during gestation than they require for maintenance and for development of the products of conception and will therefore deposit body lipid. Therefore, the energy intake of gestating sows should be limited. Lactating sows should be fed at a level to support maintenance plus requirements for milk production. Consequently, DE or ME intake can be adjusted in relation to litter size. Research has shown that in feeding sows, efficiency of utilization of energy can be improved by allowing moderate weight gains during gestation and moderate weight losses during lactation, allowing for a small positive increase in body weight in each reproductive cycle.

During growth, fiber digestibility increases as size and capacity of the digestive tract increase. Thus, the standard DE and ME values, which are normally based on digestibility and metabolism studies with growing pigs, may not be applicable to older pigs and breeding animals when high-fiber ingredients are fed.

Carbohydrates

The proximate analysis, commonly used to determine the nutrient content of a diet or feed ingredient, does not measure carbohydrate directly. Total carbohydrate is the combined nitrogen-free extract (NFE) and crude fiber. In this combined fraction, crude fiber is determined analytically and NFE, which consists primarily of sugars and starches, is then determined by difference. The very young pig does not utilize starch efficiently. When weaned before reaching 2 weeks of age, the carbohydrate fraction of the diet is therefore generally supplied in the form of sugars. For pigs of less than 7 days of age, glucose and lactose are the sugars of choice, and, after 7 days of age, fructose and sucrose can be utilized. Two weeks after birth, enzymes are present for digesting starch.

Cellulose is generally the major component of crude fiber with lesser, though variable, amounts of lignin also present. The pig does not produce enzymes for digesting cellulose or lignin; however, some microbial cellulose digestion does occur in the cecum and large intestine. The digestibility of fiber increases with increased capacity of the digestive system but varies in relation to chemical complexity of the fiber and level in the diet. It should be considered as relatively indigestible. The inclusion of high levels of fiber in the diet lowers the digestibility of dry matter, protein, and ether extract and thus also decreases the digestible energy of the diet. Increasing crude fiber in the diets of pigs fed *ad libitum* tends to reduce growth rate, despite a tendency of pigs to increase feed intake to compensate for the lower energy value of the diet. Any change observed in feed conversion, dressing percentage, and backfat thickness is generally in proportion to level and type of fiber added. If, however, energy intake is held constant, the inclusion of fiber should have no effect upon rate or efficiency of gain or upon carcass leanness.

Lipids

The term lipid is frequently used in a general sense to include both fats and oils. Some questions remain as to whether the pig has a dietary essential fatty acid requirement. There is limited direct and indirect evidence that the pig is capable of some synthesis of linoleic acid. However, based upon the triene–tetraene ratio of tissue lipids, the dietary requirement for linoleate is small and is supplied adequately by natural ingredients. The concern, therefore, is mainly with lipids as an energy source. Swine can efficiently utilize large quantities of fats and oils in their diet. The efficiency of utilization of lipids is influenced by age of the pig and by the type and molecular weight of the lipids added. Limitations to the level of lipids in swine diets are dictated by economics and the physical problems of mixing, processing, and handling diets containing large amounts of lipids.

Upon biological oxidation, lipids yield 2.25 times as much energy as carbohydrates. The inclusion of fats or oils as a replacement for a high carbohydrate source, such as corn, will increase the energy content of the diet. Since swine tend to eat to meet their energy requirement, increasing the caloric density of the diet generally results in a reduction in total feed intake. Thus, the protein, vitamin, and mineral levels of a lipid-supplemented diet should be adjusted upwards to compensate for the expected reduction in feed intake. Approximately the same proportionate reduction in feed intake will result from the addition of 5, 10, or 15 percent lipid to the diet. In spite of the decrease in total feed intake, the caloric intake of the pig will be increased. This increased caloric intake may result in increased rate of gain and increased deposition of fat in the carcass. The addition of fat to high-protein diets may not reduce feed intake or increase fat deposition to the same extent as that observed when fat is added to low-protein diets. An improvement in the efficiency of feed conversion is a consistent feature of fat-supplemented diets. However, the relative cost of fat versus carbohydrate sources of energy will determine the economic efficiency of such diets.

PROTEIN—AMINO ACIDS

Protein

Protein is generally referred to as crude protein and in a feedstuff is defined as the nitrogen content × 6.25. The adequacy of dietary protein levels is determined by the capacity of the diet to supply sufficient indispensable (essential) amino acids and, in addition, nitrogen for the synthesis of dispensable (nonessential) amino acids. The dispensable amino acids for swine are needed in normal metabolism, but dietary sources usually are not required. These amino acids are obtained either from normal dietary components or synthesized by making use of amino groups derived from amino acids that are in excess in the diet. Supplemental nonprotein nitrogen, such as urea, has not produced beneficial responses in swine fed practical-type diets.

Optimum performance requires that any indispensable amino acid be fed at the proper level and time in the feeding period and with the proper level of energy and other indispensable nutrients. Swine will perform satisfactorily if these conditions are met, even though there may be some variation in the level of crude protein in the diet. Because they are naturally leaner, gilts and boars require higher levels of crude protein to meet amino acid requirements than barrows. Also, maximal carcass leanness may require a greater intake of amino acids than maximal rate of weight gain. Protein levels that are necessary to provide the indispensable amino acids for growing swine fed grain–soybean meal-type diets are shown in Table 5.

The cereal grains often provide a major portion of the total protein. However, supplementary amino acids, either from natural protein supplements or synthetic amino acids, must be provided to ensure adequate amounts and a proper balance of the indispensable amino acids.

The availability of amino acids in the protein of common feed ingredients fed to swine has not been adequately determined. Based upon results obtained with other species, values ranging from 80 to 90 percent are often assumed. Requirements for protein and amino acids listed in Tables 5 through 8 represent, in most instances, the levels of these nutrients required for swine fed grain–soybean meal diets. For example, if a combination of grain and soybean meal furnishes 16 percent protein and 0.70 percent total lysine and is to be fed to swine in a weight range of 20 to 35 kg, it can be assumed that the physiologically available lysine requirement is between 0.56 and 0.63 percent. However, to account for the small portion that is not available, the lysine requirement (allowance) listed in Table 5, for pigs in this weight range, is 0.70 percent.

Amino Acids

Requirements for indispensable amino acids by swine of various weights and in different stages of production are shown in Tables 5 through 8. In all cases, the requirements correspond to the amount of natural isomer (L), the form in which amino acids occur in proteins. When amino acid supplements are provided, DL-methionine can replace the L form in meeting the need for methionine. D-Tryptophan has a biological activity of about 60 percent relative to L-tryptophan for the growing pig. Thus, 0.15 percent DL-tryptophan is equivalent to 0.12 percent L-tryptophan in meeting the needs of the growing–finishing pig for this amino acid. It is assumed that the pig can utilize D-phenylalanine to some extent in meeting the total need for phenylalanine + tyrosine, but the efficiency of D-phenylalanine utilization is not known.

Pigs can synthesize arginine at a rate sufficient to meet 60–75 percent of the requirement for normal growth, but the remainder must be provided from a dietary source to fulfill the total need of growing–finishing swine. For gravid and nongravid postpubertal swine, synthesis by the animal completely satisfies the arginine need. Cystine can satisfy at least 50 percent of the total need for methionine + cystine (sulfur amino acids), and methionine can meet the need in the absence of cystine. Phenylalanine can meet the total requirement for phenylalanine + tyrosine, since it can be converted to tyrosine. Tyrosine is not converted to phenylalanine, but it can satisfy 50 percent of the total need for the two amino acids.

The amino acid requirements of growing–finishing swine, expressed in terms of dietary concentration, increase as the levels of dietary protein or caloric density of the diet increases. Because the amino acid concentration of lean tissue remains essentially constant with age, and maintenance needs constitute a small percentage of total needs, it is assumed that the requirements for indispensable amino acids remain a constant percent of the protein with advancing age and weight. Thus, knowing the requirements for individual amino acids at 16 percent protein for pigs weighing 20 to 35 kg and knowing levels of protein (from grain–soybean meal mixtures) that permit optimal performance in pigs at other stages of growth allow calculation (by linear extrapolation) of requirements for all weight ranges shown in Table 5. In most cases, requirements determined experimentally have been in close agreement with extrapolated values. Exceptions have been lysine for pigs weighing 1 to 5 and 5 to 10 kg, where determined requirements have been somewhat higher than those predicted by extrapolation. Also, the methionine + cystine requirement of swine weighing 60 to 100 kg is lower than that predicted by extrapolation. The levels of amino acids shown in Tables 5 and 6 are adequate to support normal growth and performance, and they apply to diets of the caloric density indicated in Table 5. The lack of adequate quantitative information concerning the effects of caloric density of the diet and metabolizable energy content of feedstuffs for swine of various weights and stages of production precludes setting forth amino acid requirements on the basis of energy density of the diet. Where data are available, should caloric density increase or decrease from the values given, amino acid requirements may be adjusted upward or downward, respectively.

The requirements for pregnant gilts and sows are based upon amounts required for satisfactory retention of nitrogen during the late stages of pregnancy and are at least adequate to support development of a normal litter. The requirements for lactation either have been determined experimentally or have been extrapolated from published requirements for maintenance of adult female swine and from amounts calculated to be required to support good milk production.

MINERALS

At least 13 inorganic elements are known to be required by the pig, including calcium, phosphorus, potassium, sodium, chlorine, magnesium, sulfur, zinc, iron, manganese, copper, iodine, and selenium. In addition, vanadium, chromium, nickel, tin, molybdenum, silicon, and fluorine, which have been shown to be required by one or more species, probably are also required by the pig but at such low levels that their dietary essentiality has not been demonstrated.

Functions of the inorganic elements are extremely diverse, ranging from structural functions in some tissues to a wide variety of regulatory functions in many others. The increasing trend toward confinement rearing of pigs, without access to soil or forage, increases the importance of meeting their dietary mineral requirements. Requirements for the individual elements at various stages of the life cycle are given in Tables 5 through 8 and are discussed below.

Calcium and Phosphorus

Calcium and phosphorus are of major importance for skeletal development and for many other physiological functions. For maximum performance, minimum dietary levels of each are necessary, as well as the correct ratio of one to the other. Requirements, as shown in Tables 5 through 8, are based upon the feeding of a properly fortified grain–soybean meal diet. The quantitative need for calcium and phosphorus may be modified by other dietary factors, such as vitamin D, magnesium, or the presence of phytic acid in plant materials. Levels that are adequate for maximum gain in body weight are not necessarily adequate for maximum bone development. Borderline deficiency may go unnoticed in the growing–finishing animal but cause serious consequences in those saved for breeding purposes.

Information on the calcium and phosphorus requirements of gilts, sows, and boars is very limited. During pregnancy the physiological requirement increases in proportion to the need for fetal growth and reaches a maximum late in the gestation period. Because feeding practices during pregnancy vary greatly, diets should be formulated to meet daily requirements as shown in Table 8. When the total dietary intake of breeding animals is severely restricted the animals may receive too little calcium and phosphorus, even though the dietary concentration meets the requirement as shown in Table 7. Excessive intake of calcium or phosphorus may lower performance of growing–finishing swine, especially when an excess of calcium interacts with zinc to cause a zinc deficiency.

The form in which phosphorus exists in natural feedstuffs influences the efficiency of its utilization. In grains and plant protein supplements, about two-thirds of the phosphorus is in the less available phytate form. Utilization of phytate phosphorus is influenced by phytase present in plant materials and the intake of vitamin D, calcium, and zinc, as well as such factors as the pH of alimentary tract and the ratio of calcium to phosphorus in the diet. Estimates of the availability of total plant phosphorus range from 20 to as high as 60 percent.

A wide range of calcium and phosphorus sources simplifies dietary fortification (Table 11). The desired ratio of between 1.0 and 1.5 calcium to 1.0 total phosphorus in a grain–soybean meal diet can be attained easily by selection of suitable supplements.

Signs of calcium and phosphorus deficiency are similar (Table 1) and are not unlike those seen in vitamin D deficiency.

Sodium and Chlorine

Sodium and chlorine are the principal extracellular cation and anion, respectively, in the body, and chlorine is the chief anion in gastric juice. Recent research has confirmed that a level of 0.20 to 0.25 percent added sodium chloride will meet the dietary sodium and chlorine requirements of the growing–finishing pig fed a grain–soybean meal diet. Little or no information is available on the requirement for breeding-age boars or for gilts and sows in gestation or lactation. Until more definitive information is available, a level of 0.4 percent added sodium chloride is suggested for boars and pregnant animals and 0.5 percent for lactating sows.

When a diet deficient in sodium chloride is fed to growing pigs, depressed performance will be evident within a few weeks. Deficiency signs are presented in Table 1.

Swine can tolerate high dietary levels of sodium chloride, but, at a high level of intake, it is absolutely necessary to provide ample and readily available drinking water. As little as 1.0 percent dietary sodium chloride has produced toxicity signs and death when water has been restricted. The sodium ion is responsible for the adverse physiological reaction. Signs of toxicity are presented in Table 2.

Potassium

Potassium is an important mineral involved in electrolyte balance and neuromuscular function and serves as a monovalent cation to balance anions intracellularly, much as sodium functions extracellularly. Experimental estimates of the dietary potassium requirement are 0.27 to 0.39 percent for pigs weighing 1 to 4 kg, 0.26 percent for pigs weighing 5 to 10 kg, 0.23 to 0.29 percent for pigs weighing 16 kg, and less than 0.20 percent for pigs weighing 20 to 35 kg. The daily potassium requirement of pigs weighing 45 kg is less than 5 g. Excesses of dietary chloride or sulfate ions increase the potassium requirement. As dietary potassium is increased, there is an increased need for drinking water. Grain–soybean meal diets contain much higher levels of potassium than the requirements listed in Tables 5 and 7, and no potassium deficiency signs have been observed in swine fed these diets.

Signs of potassium deficiency in young pigs receiving purified diets were, progressively: anorexia, rough hair coat, emaciation, inactivity, and ataxia (Table 1). Electrocardiograms taken during potassium deficiency reveal reduced heart rate and altered electrocardial intervals.

Necropsy of potassium-deficient pigs reveals no unique pathology.

Magnesium

Magnesium is a cofactor in many important enzyme systems and is a constituent of bone. The magnesium requirements of growing–finishing and adult swine are not known. Young, artificially reared pigs were shown to have a requirement of between 325 and 500 mg magnesium per kilogram of diet. Grain–soybean meal diets generally contain sufficient magnesium (1 g or more per kilogram of diet) to prevent deficiency signs. Similarly, milk contains adequate magnesium to protect suckling pigs.

Signs of deficiency, in order of appearance, are: hyperirritability, muscular twitching, reluctance to stand, stepping syndrome, weak pasterns, loss of equilibrium, and tetany followed by death (Table 1).

Iron

Iron is required for the formation of hemoglobin, myoglobin, ferritin, hemosiderin, transferrin, and all iron-containing enzymes. Pigs are born with about 50 mg of iron in their body, most of which (80 percent) is present in erythrocytes as hemoglobin. Necessary iron retention in the nursing pig to maintain levels of hemoglobin and storage iron range from 7 to 16 mg daily or 21 mg per kilogram of body-weight gain. Sow's milk contains an average of 1 mg of iron per liter and thus, if not supplemented, will result in the rapid development of anemia. The feeding of high levels of different iron compounds to gestating and lactating sows has not effectively increased the iron content of the milk. The oral iron requirement of baby pigs fed milk or purified liquid diets is 60 to 150 mg per kilogram of milk solids. It appears that the requirement of baby pigs receiving a dry (casein-based) diet is about 50 percent higher per unit of dry matter than when fed a similar diet in homogenized liquid form. Germ-free baby pigs have a dietary iron requirement similar to that of conventionally reared baby pigs.

Numerous studies have shown the effectiveness of a single intramuscular injection of 100 to 200 mg of iron, as iron dextran or iron dextrin complexes, given in the first 3 days of life. Over 90 percent of the injected iron is utilized over the next few weeks as an anemia preventative. The postweaning dietary iron requirement is about 80 ppm and diminishes in later growth and maturity, since there is a smaller increase in blood volume with increasing body weight. Feed ingredients in a balanced diet usually supply enough iron to meet postweaning requirements. Some calcium and phosphorus sources, such as feed grade defluorinated phosphate and dicalcium phosphate, contain from 0.6 to 1.0 percent of iron, of which about 60 percent is available to the pig.

Availability of iron from different sources (Table 11) varies greatly. Ferrous sulfate and ferric ammonium citrate are effective in preventing iron-deficiency anemia, but an iron compound with low solubility, such as ferric oxide, is ineffective. Ferrous carbonate is much less effective than ferrous sulfate.

Dietary iron is effective in detoxifying gossypol-containing diets. The addition of iron from soluble sources to the diet equal to the weight of free gossypol improves growth rate, reduces toxicity, and helps prevent accumulation of gossypol in the liver.

Blood hemoglobin concentration is a rapid, reliable indicator of the iron status of the pig. The following hemoglobin levels can be used as indicators of the iron status of pigs between birth and 8 weeks of age:

Blood Hemoglobin (g/100 ml)	Comment
10 or above	Normal level; adequate iron and optimum performance
9	Minimum level required for average performance and the dividing line between normality and anemia
8	Borderline anemia; iron treatment needed
7 or below	Anemic condition that has been shown to retard growth rate
6 or below	Severe anemia accompanied by marked reduction of performance
4 or below	Severe anemia that can be expected to result in increased mortality rate

Iron-deficiency anemia is of the hypochromic-microcytic type. Anemic pigs show signs of poor growth, listlessness, rough hair coat, wrinkled skin, and paleness of mucous membranes. Fast-growing anemic pigs may die suddenly of anoxia. A characteristic sign is labored breathing after minimal activity or a spasmodic jerking of the diaphragm muscles from which the term "thumps" arises. Necropsy findings include an enlarged and fatty liver, thin watery blood, ascites, marked dilation of the heart, and an enlarged firm spleen (Table 1). In 3- to 10-day-old pigs the toxic oral dose of iron from ferrous sulfate is approximately 600 mg/kg of body weight. Clinical signs of toxicity are observed within 1 to 3 hours after iron is fed (Table 2).

Zinc

Zinc is a component of many metalloenzymes and the hormone insulin and is thereby involved in protein, carbohydrate, and lipid metabolism.

The dietary zinc requirement is influenced by many diet-related factors, including phytic acid or plant phytates, calcium, copper, cadmium, cobalt, histidine, as well as type and level of protein. The requirement of growing pigs receiving semipurified diets containing isolated soybean protein, or natural corn–soybean meal diets containing the recommended calcium level, is about 50 ppm.

Boars have a slightly higher zinc requirement than gilts, and both boars and gilts have a higher requirement than barrows. When dietary calcium level is excessive, the zinc requirement is increased. A zinc level of 33 ppm in corn–soybean meal gestation and lactation diets of sows through five parities was adequate for optimal gestation performance, but not for lactation. Because of the absence of phytic acid or plant phytates, the zinc requirement of baby pigs receiving a casein–glucose diet is reduced to about 15 ppm.

Signs of zinc deficiency in growing pigs include parakeratosis and reduced appetite with reduced rate and efficiency of gain. Markedly reduced levels of serum zinc, alkaline phosphatase, and albumin are also found. Gilts receiving zinc-deficient diets during gestation and lactation produce fewer and smaller pigs that at birth have a reduced serum and tissue zinc level. Testicular development of the zinc-deficient growing boar and thymic development of the zinc-deficient baby pig are retarded (Table 1).

Zinc may be increased to 1,000 ppm in the diet without producing signs of toxicity, but a dietary zinc level of 2,000 ppm from zinc carbonate produced the following toxic signs: growth depression, arthritis, hemorrhage in axillary spaces, gastritis, and enteritis (Table 2).

Manganese

Manganese functions as a component of several enzymes involved in carbohydrate, lipid, and protein metabolism and is essential for synthesis of chondroitin sulfate, which is a component of mucopolysaccharides in the organic matrix of bone.

Minimum requirements for manganese are not well defined. Growth is normal when pigs are fed a purified diet containing as little as 1.5 mg/kg of diet. Continued feeding of a lower level of 0.5 mg/kg of diet interferes with normal development and reproduction. Signs of manganese deficiency have included abnormal skeletal growth with altered ratio of fat to lean body tissue; absence of, or irregular, estrual cycles; poor mammary development and lactation; resorption of fetuses; and small, weak pigs at birth (Table 1).

There is some evidence that diets containing commonly used feed ingredients should contain higher levels of manganese than the amount required in purified diets and that excessive dietary levels of calcium and phosphorus may reduce manganese absorption. For gestation and lactation a minimum of 10 mg/kg of diet is suggested. While the toxic level of manganese is not well established, depressed feed intake and reduced rate of gain have been observed when pigs were fed a diet containing 4,000 mg/kg (Table 2).

Copper

Copper is essential for the synthesis and activation of several oxidative enzymes necessary for normal metabolism in the pig. A deficiency of copper leads to poor iron mobilization, abnormal hematopoiesis, keratinization, and synthesis of collagen, elastin, and myelin. Low fertility has been associated with copper deficiency in several animal species, but not in swine. A level of 6 ppm of copper in the diet for the very young pig seems to be adequate, and the requirement is probably no greater for later stages of growth. Definitive information on the requirements for pregnancy and lactation is lacking. Signs of deficiency include leg weakness and ataxia. A subclinical deficiency is associated with reduced serum copper and ceruloplasmin and a microcytic hypochromic anemia (Table 1). While availability does vary, the copper requirement can be effectively met by the use of supplemental copper sulfate, copper carbonate, or copper oxide.

Copper toxicity has been reported at levels above 250 ppm, particularly when iron and zinc levels are limiting or when calcium is in excess. Toxicity signs are presented in Table 2.

Iodine

Iodine is a component of thyroxine and triiodothyronine, which are important in the regulation of metabolic rate.

The dietary iodine requirement of the pig is increased by goitrogens and excessive levels of arsenic, fluoride, cobalt, calcium, and sodium chloride. Experimental estimates of the requirement for normal growth and thyroid size range from 0.05 to 0.14 ppm, and, in the absence of excesses of the above interrelated minerals, a dietary iodine level of 0.14 ppm seems to be adequate for all stages of the life cycle. Calcium and potassium iodate and pentacalcium orthoperiodate are nutritionally available forms and are more stable in salt and feed mixtures than sodium or potassium iodides. If salt contains 0.007 percent iodine, the requirement can be met by incorporating 0.2 percent salt in the diet.

Signs of iodine deficiency observed in pigs born to sows on goitrogenic diets are hairlessness, thickened skin, and myxedema. Most of the pigs are born alive, but are weak and usually die within a few hours. At necropsy, the thyroid is enlarged and hemorrhagic (Table 1).

Iodine may be increased to 400 ppm in the diet of the growing pig without depressing growth rate or the efficiency of feed utilization. Dietary iodine levels of 800 ppm or more depress growth rate, feed intake, hemoglobin level, and liver iron concentration, while bringing about an increase in serum iron and thyroid weight (Table 2).

Selenium

The dietary requirement for selenium is between 0.1 and 0.2 mg/kg of diet and is inversely related to vitamin E level. Selenium is an essential component of the enzyme glutathione peroxidase, which functions in peroxide reduction. Thus, the mutual sparing effect of selenium and vitamin E stems from their shared antiperoxidant roles. High levels of vitamin E will not eliminate the need for selenium. Certain soils of the United States and Canada are low in selenium, and the feeding of diets formulated from ingredients grown in such regions often results in a selenium deficiency. Incidence and degree of selenium deficiency may be increased by environmental stress.

The primary biochemical change in selenium deficiency is a decline in glutathione peroxidase activity. Serum transaminases, lactic dehydrogenase, and creatine phosphokinase may be elevated as a result of tissue damage. Sudden death is a prominent feature of the selenium-deficiency syndrome. Gross necropsy lesions of selenium deficiency are identical to those of vitamin E deficiency (Table 1). These include massive hepatic necrosis (hepatosis dietetica) and edema of the spiral colon, lungs, subcutaneous tissues, and submucosa of the stomach. Bilateral paleness and dystrophy of the skeletal muscles (white muscle disease) are often found. Occasionally, mottling and dystrophy of the myocardium (mulberry heart disease) are also observed.

Selenium, when fed to growing swine as sodium selenite, sodium selanate, selenomethionine, or seleniferous corn, does not produce toxicity at levels as high as 5 mg of selenium per kilogram of diet. Levels from 7.5 to 10 mg/kg may produce toxicity. Signs of toxicity include anorexia, hair loss, fatty infiltration of the liver, degenerative changes in liver and kidney, swelling, and occasional separation of hoof and skin at the coronary band (Table 2). Dietary arsenicals help to alleviate selenium toxicity.

Cobalt

Cobalt does not appear to be a dietary requirement except as a part of the vitamin B_{12} molecule. Since the intestinal flora of the pig is capable of synthesizing vitamin B_{12}, a minimum level of dietary cobalt is required for this process to occur. Such synthesis assumes greater importance if dietary vitamin B_{12} is limiting. There is also some evidence that cobalt may have a "sparing action" on zinc in zinc deficiency. No dietary requirement for cobalt has been established.

A level of 400 mg of cobalt per kilogram of diet is toxic to the young pig and may cause anorexia, stiff-leggedness, humped back, incoordination, muscle tremors, and anemia (Table 2).

VITAMINS

Vitamins are organic compounds required in small amounts for normal growth and reproduction and for maintaining the health of swine. Some vitamins are essential in metabolism but may not be required in the diet, since they can be synthesized readily from other food constituents. An example of this is the production of niacin from tryptophan. Bacteria in the intestinal tract also are capable of producing vitamins, such as vitamin K and vitamin B_{12}, which can then be made available to the animal. The vitamins are generally divided into fat-soluble vitamins A, D, E, and K and water-soluble B vitamins and vitamin C.

Fat-Soluble Vitamins

Each of the four fat-soluble vitamins occurs naturally in a variety of vitamin or provitamin forms in feedstuffs and each is produced in synthetic forms that have a high degree of vitamin activity. The increasing trend toward rearing pigs in confinement without access to forage or sunlight increases the importance of meeting the dietary vitamin requirements presented in Tables 5 through 8 and discussed below.

Vitamin A The vitamin A requirement of swine can be met by either vitamin A or by provitamin A in the form of beta-carotene. Beta-carotene is the standard for provitamin A, and for the rat 1 IU of vitamin A activity is equal to 0.6 μg of beta-carotene. The conversion of carotene to vitamin A in the pig is less efficient. Based upon liver storage, the biopotency of 1 mg of beta-carotene ranges from 200 to 500 IU of vitamin A activity compared to 1,667 IU of vitamin A activity for the rat. Feed ingredients contain a mixture of carotenoids, some of which have less biological activity than beta-carotene. For swine, 1 mg of the total carotenoid material in corn provides about 250 IU of vitamin A activity.

International standards for vitamin A are based upon its utilization by the rat and are as follows: 1.0 IU of vitamin A activity = 1.0 U.S.P. unit = vitamin A activity of 0.300 μg of crystalline vitamin A alcohol (retinol), which corresponds to 0.344 μg of vitamin A (retinyl) acetate or 0.550 μg of vitamin A (retinyl) palmitate.

Vitamin A is essential for the normal maintenance and function of the eyes and of the epithelial tissues of the respiratory, reproductive, nervous, and genitourinary systems. Recommended dietary requirements for vitamin A or beta-carotene are shown in Tables 5 through 8. Taken individually, night blindness, elevated pressure of cerebrospinal fluid, and reduced growth rate are poor criteria for assessing the vitamin A status of swine, but collectively they provide a reliable indicator. Deficiency signs are described in Table 1. Swine have the ability to store vitamin A in the liver, which is then available during periods of stress or low intake. The excessive intake of nitrate or nitrite may increase the dietary vitamin A requirement.

Vitamin D Vitamin D_2 (ergocalciferol) and vitamin D_3 (cholecalciferol) are both equally effective in meeting the vitamin D requirements of swine. One international unit (IU) of vitamin D is defined as the biological activity of 0.025 μg of cholecalciferol. Cholecalciferol is converted to 25-hydroxy D_3 by the liver and is the major circulatory metabolite of vitamin D_3, but for conversion to the biologically active form of the vitamin it must undergo further hydroxylation to 1,25-dihydroxy D_3 in the kidney. This is the hormonal form that stimulates intestinal calcium and phosphate transport, bone calcium mobilization, and renal calcium reabsorption. Other vitamin D_3 metabolites may also be of importance in calcium and phosphorus homeostasis.

The dietary vitamin D_2 requirement of the baby pig, reared on a purified diet containing casein as the protein source, is 100 IU/kg of diet. When casein is replaced by isolated soybean protein, which has rachitogenic activity, the vitamin D_2 requirement is higher. The minimum requirement of growing pigs receiving a grain–soybean meal diet is 200 IU/kg.

Grains, grain by-products, and protein feedstuffs are practically devoid of vitamin D. Therefore, unless swine are exposed to the ultraviolet rays of the sun, the diet should be fortified with this vitamin.

The principal manifestation of vitamin D deficiency is a disturbance of calcium and phosphorus absorption and metabolism with insufficient calcification of bones. In young growing pigs, the result is rickets, while in mature swine diminished mineral content with softening of the bone (osteomalacia) results. Serum calcium and phosphorus are reduced and serum alkaline phosphatase activity is increased. In severe vitamin D deficiency, serum magnesium may also be low and pigs may exhibit signs of calcium and magnesium deficiency, including tetany (Table 1).

Weanling pigs that were supplemented with 250,000 IU of vitamin D_3 daily for 4 weeks had reduced body-weight gain and reduced weight of liver, radius, and ulna. Pigs receiving this level of vitamin D_3 had periods of inappetance, and, at necropsy, pathological calcification was observed in the aorta, heart, kidney, and lung (Table 2).

Vitamin E Vitamin E activity is a function of several tocopherols, and acts primarily as a lipid-soluble antioxidant. The dietary requirement for vitamin E is dependent upon levels of dietary selenium and polyunsaturated fatty acids, as well as the presence or absence of other antioxidants. Extremes of temperature and exercise may increase the requirement. The tocopherols differ considerably in their biological activity with *d*-α-tocopherol being most active. One international unit (IU) of vitamin E activity is defined as the biological activity of 1 mg *dl*-α-tocopheryl acetate.

In the presence of adequate selenium, a total of 10 to 15 IU of vitamin E per kilogram of diet is adequate for grain–soybean meal diets. The level necessary to prevent deficiency signs, however, may be considerably higher in the absence of adequate selenium and/or in the presence of high levels of prooxidants.

Signs of deficiency are the same as those encountered in selenium deficiency. Elevated serum transaminases, lactic dehydrogenase, and creatine phosphokinase are found early in the development of the deficiency state. Hepatic necrosis, muscular dystrophy, and edema, as well as sudden death, are among other features shared with selenium deficiency (Table 1).

A toxicosis due to high intakes of vitamin E has not been demonstrated in swine. Levels as high as 100 IU/kg diet have been fed to growing pigs and over 300 IU/kg diet have been fed to boars and sows without toxic effects.

Vitamin K The pig requires vitamin K for the formation of prothrombin and other plasma proteins essential for normal clotting of blood. The best natural sources of the vitamin include the legumes and other green forage materials. Synthesis of vitamin K_2 by the gastrointestinal microflora is an important factor influencing the dietary requirement.

A hemorrhagic condition in the growing pig, believed to be a deficiency of vitamin K, has been associated with the consumption of mold-contaminated diets. Signs of deficiency have been produced in newborn pigs housed in wire-bottomed cages and fed a synthetic diet containing an antibiotic and a sulfa drug. Lack of the vitamin increases prothrombin time and clotting time and may result in internal hemorrhage. Signs of deficiency are eliminated by the addition of vitamin K or water-soluble synthetic forms of the vitamin to the diet (Table 1).

The most common synthetic materials with vitamin K activity for dietary use are menadione sodium bisulfite, menadione sodium bisulfite complex, and menadione dimethyl pyrimidinol bisulfite. Such water-soluble forms have biological activity related primarily to their menadione content. The occasional appearance of signs of vitamin K deficiency under field conditions has led to the common addition of vitamin K to swine diets, particularly where pigs are reared in confinement. If there is evidence of a deficiency, or if there is need to supply vitamin K activity for preventative purposes, it is suggested that the diet be supplemented with 2.0 mg of menadione per kilogram.

Water-Soluble Vitamins

Deficiencies of niacin, pantothenic acid, riboflavin, choline, and vitamin B_{12} may occur in pigs fed unsupplemented grain–soybean meal diets. Thiamin, vitamin B_6, biotin, and folacin are contained in many feed ingredients at levels that furnish more than the pig's requirement. Ascorbic acid (vitamin C) is produced by the pig and, under most conditions, is not required in the diet. Water-soluble vitamin requirements are presented in Tables 5 through 8 and discussed below.

Thiamin Thiamin is essential for swine, but virtually all diets contain an abundant quantity of this B vitamin. Grains are particularly rich in thiamin. Signs of deficiency in swine have been produced only under experimental conditions. Raw fish contains a thiaminase that renders thiamin inactive, and bracken fern contains an antithiamin substance of nonenzymatic nature.

Thiamin functions in intermediary metabolism primarily in its coenzyme form, thiamin pyrophosphate (TPP), and as such is involved in decarboxylation reactions. In either crystalline form or in food, thiamin is heat labile. Thus, drying of grains and cooking of soybeans lower the concentration of available thiamin in these ingredients. Signs of thiamin deficiency are presented in Table 1.

Riboflavin Riboflavin functions in the pig in two coenzymes essential in oxidation-reduction reactions, flavin mononucleotide (FMN) and flavin-adenine dinucleotide (FAD). The riboflavin requirements of the baby pig receiving semipurified liquid or dry diets, and of the weanling pig receiving natural diets, is 3 mg/kg of diet. When expressed as a concentration in the diet, the requirement is reduced as body weight increases. Intestinal bacterial synthesis of riboflavin reduces dietary needs, and more of the vitamin is required when fat is added to the diet. The requirement is most closely related to energy expenditure and is consistently 700 to 800 mg per megacalorie of dietary metabolizable energy. The minimum dietary riboflavin requirement of the sow for gestation and lactation is about 3 mg/kg.

Signs of riboflavin deficiency in the young growing pig include slow growth, vomiting, cataracts, abnormal stiffness of gait, seborrhea, and alopecia. A normocytic anemia and myelinic degeneration of nerve tissue have been reported. In sows, riboflavin deficiency results in poor reproduction and lactation performance (Table 1).

Niacin Niacin is required by all living cells, and it is an essential component of important enzyme systems involved in lipid, carbohydrate, and protein metabolism. As nicotinamide, it is a component of the coenzymes nicotinamide-adenine dinucleotide (NAD) and nicotinamide-adenine dinucleotide phosphate (NADP). In the diet, nicotinamide can substitute for nicotinic acid on an equal weight basis. Signs of deficiency in the pig include anorexia and decreased rate of gain, followed by diarrhea, occasional vomiting, and an exfoliative type of dermatitis and loss of hair (Table 1). Diets based upon cereal grains are low in available niacin; thus crystalline nicotinic acid is generally added to satisfy requirements.

Two factors must be considered in evaluating the adequacy of niacin in diets:

1. Niacin occurs in cereal grains in a bound form, which is largely unavailable to the pig. This fact is not revealed in the conventional niacin assays, which merely indicate the total content of the vitamin.
2. Because of the conversion of tryptophan to niacin by the pig, the tryptophan level of the diet is important in determining the niacin requirement. Each 50 mg of tryptophan, in excess of the tryptophan requirement, will yield 1 mg of niacin.

Pantothenic Acid Pantothenic acid is distributed widely in feed ingredients of plant and animal origin. It is required by the pig as a component of coenzyme A, an important enzyme in carbohydrate and fatty acid metabolism.

The vitamin is commercially available as the calcium salt (calcium pantothenate), which is used as the supplemental form. Products marketed are commonly a mixture of the *d* and *l* forms of calcium pantothenate. Since only the *d* isomer has biological activity, in formulating diets or premixes the guarantee should be stated in terms of this form only.

Pantothenic acid deficiency is most commonly seen in the young pig and is revealed as leg stiffness and locomotor incoordination, which sometimes gives the appearance of "goose-stepping." It should be pointed out that while a deficiency of pantothenic acid will cause goose-stepping, other conditions, not well defined, also may lead to the development of a similar gait. Signs of pantothenic acid deficiency may also include slow growth and poor condition of the hair and skin. In the sow, following a prolonged inadequate intake of this vitamin, the above signs of deficiency may appear in pigs shortly after birth. Such signs in the newborn will be evident before reproductive function is impaired (Table 1).

Vitamin B_{12} Vitamin B_{12} is required for the maturation of red blood cells and is involved in numerous other metabolic functions. Feed ingredients of animal origin contain substantial, but highly variable, quantities of the vitamin. Synthesis of vitamin B_{12} by intestinal bacteria serves to supplement dietary sources.

Vitamin B_{12} contains the trace element cobalt, and vitamin B_{12} synthesis by intestinal flora is dependent upon the presence of this mineral in the feed. This is the only established function of cobalt as an essential nutrient.

In the growing pig a deficiency of vitamin B_{12} reduces growth. In the reproducing animal, litter size and pig survival are reduced (Table 1). When a sufficient quantity of the vitamin is not supplied by ingredients of animal origin, a supplemental level is recommended at all stages of the life cycle (Tables 5–8).

There is some evidence that the reproductive performance of sows may be improved by the inclusion of higher than recommended levels of vitamin B_{12}. The response is evidenced by an increase in the number and weight of pigs at birth. Response to such elevated levels is not consistent and may relate to variable synthesis by intestinal bacteria or to differences in utilization of the vitamin.

Choline Choline does not strictly qualify as a vitamin because it is required in the diet at levels far greater than those of the other vitamins, and because it is actually a structural component of fat and nerve tissue. Moreover, choline is not known to participate in any enzyme system. Nonetheless, because of its biological function in cell structure (component of phospholipid), lipid transport, and nerve impulse transmission (acetyl choline), choline is generally considered along with the vitamins.

Choline is an important source of labile methyl groups that function in a variety of one-carbon transfer reactions referred to as transmethylation, and the major portion of the dietary choline required is necessary for this function. In the pig, methionine (also a methyl donor) can completely replace that portion of the choline needed for transmethylation. Thus, at methionine levels in excess of the physiological requirement, 4.3 mg methionine provides the same methylating capacity as 1 mg of choline.

Choline deficiencies have been encountered in baby pigs fed a high fat synthetic milk diet containing 0.8 percent methionine or less. Gestating sows fed corn–soybean meal diets have responded to supplemental choline with increased litter size at birth. Signs of choline deficiency in the growing pig are depressed growth rate, unthriftiness, and fatty infiltration of the liver (Table 1).

Vitamin B_6 Vitamin B_6 exists in three forms in feedstuffs: pyridoxine, pyridoxal, and pyridoxamine. Pyridoxal phosphate is the coenzyme form of the vitamin and is essential for the biological activity of decarboxylases, dehydrases, synthetases, transaminases, and racemases involved in amino acid metabolism. Vitamin B_6-containing enzymes are involved in the synthesis and catabolism of all amino acids. In experimentally produced vitamin B_6 deficiency, the conversion of tryptophan to niacin is blocked.

Because of its wide distribution in natural feed ingredients, vitamin B_6 is seldom deficient in swine diets. Consequently, it is not generally added in supplemental form. For young pigs the dietary requirement is 1.5 mg/kg and for the growing–finishing pig 1.1 mg/kg (Table 5).

Biotin Biotin is a functional component of enzymes required in carboxylation reactions such as acetyl-CoA carboxylase, an enzyme needed in fatty acid synthesis. The small amount required by the pig is usually supplied by the diet and is augmented by microbial synthesis of the vitamin in the digestive tract. Only after the feeding of diets containing high levels of raw egg white, containing avidin, which forms a complex with biotin, or, following the inclusion of high levels of sulfa drugs to eliminate microbial synthesis, can a deficiency be produced. Clinical signs of deficiency include a dermatosis and spasticity of the hind legs (Table 1).

Factors that may influence the dietary need for biotin include the possible sparing effect of vitamin B_{12}, the destruction of biotin caused by rancidity, and the variability of bound and free biotin in feed ingredients. Performance of pigs has generally not been improved by biotin supplementation of grain–soybean meal diets. It is noteworthy, however, that wheat is low in available biotin, containing only about half the quantity present in corn, sorghum, and barley.

Folacin Folacin has an essential role in the normal metabolic function of body cells. As a constituent of the folate coenzymes, it is involved in the incorporation of single carbon units into larger molecules. Deficiency signs have been reported in young pigs only when fed diets containing folacin antagonists or high levels of sulfa drugs. Weakness, poor growth, and a normocytic anemia were evidence of the deficiency (Table 1). The folacin content of ingredients commonly used in swine diets, plus bacterial synthesis in the intestinal tract, seems to be sufficient to meet the requirement of the pig.

Ascorbic Acid The pig synthesizes ascorbic acid at a level that meets requirements for normal growth and skeletal development. High levels are found in sow's colostrum and milk and in the blood of newborn pigs. In some experiments supplemental levels of ascorbic acid have been associated with improved growth rate. Reasons for such a response are not known. It has been suggested that under conditions of environmental stress there may be need for a dietary source of the vitamin. In poultry some evidence for such a requirement is reported. Very high levels of ascorbic acid in the growing–finishing pig diet (0.5 percent) have been shown to decrease the absorption or retention of copper and to increase iron absorption.

WATER

Swine receive water from three sources, namely, metabolic water from the breakdown of carbohydrate, fat, and protein; water that is a component of feedstuffs; and water that is drunk. The latter makes up a large portion of the normal intake, although all that is required may be supplied by liquid feeds such as whey.

Water is involved in many physiological functions necessary for maximum animal performance. Among these are temperature regulation, transport of nutrients and wastes, metabolic processes, lubrication, and milk production.

The water requirements of swine are variable and governed by many factors. Water accounts for as much as 80 percent of body weight at birth and declines to approximately 50 percent in a finished market animal. The need for water is increased when fecal water excretion is high (diarrhea). Likewise, excessive urinary excretion, as may be caused by high salt or protein intake, markedly increases the water requirement. High ambient temperature, fever, and lactation are other conditions that increase water requirement. The minimum requirement is that amount needed to balance water losses plus the amount needed for the formation of new tissue or products.

Water requirement has a relationship to feed intake and to body weight. Under normal conditions swine will consume 2.0 to 5.0 kg of water per kilogram of dry feed or 7 to 20 kg of water per 100 kg of body weight daily. The wide range of consumption per unit of body weight is influenced by age, with the young animal having the higher requirement. Older swine approach the higher level of water intake when fed a highly palatable liquid feed. A weight ratio of 3 parts water to 1 part of dry feed is usually recommended for liquid feeding systems, but when the ambient temperature exceeds 35°C the pig may desire more water and refuse a portion of the solids if no supplemental water is available.

Water can serve as a vehicle for dewormers, medicinals, oral vaccines, or as a carrier for water-soluble nutrients when administered through a properly controlled dispensing system. Water may contain harmful levels of agricultural or industrial chemicals if the supply originates from shallow wells or if wells collect surface runoff. An example is nitrate contamination. An informative publication is *Nutrients and Toxic Substances in Water for Livestock and Poultry*, National Academy of Sciences, 1974.

Temperature of the water will affect volume intake. Additional energy is required to warm liquids consumed at temperatures below that of the body. Lactating sows must have unlimited access to water if they are to milk adequately, and suckling pigs need water in addition to that in sows' milk for optimum performance. Free access to water located near feed dispensers is desirable.

ANTIBACTERIAL FEED ADDITIVES

Antibiotics and other compounds with antimicrobial action, while nonnutrients, are extensively used as feed additives for swine. Such widely accepted use of these compounds relates to an improvement in growth rate and feed conversion and to reduced mortality and morbidity, particularly in young swine. Approved antibacterial agents commonly added to swine feeds in the United States and Canada include bacitracin, bambermycins, carbadox, chlortetracycline, lincomycin, oleandomycin, oxytetracycline, penicillin, streptomycin, tylosin, virginiamycin, arsenicals, nitrofurans, and sulfa drugs.While not approved for use in the United States or Canada, the addition of 125 to 250 ppm of copper as a growth promoter in growing and finishing feeds is common in Great Britain and a number of other countries.

How the low-level consumption of these compounds, which differ widely in chemical composition and bacterial spectrum, influences performance is not well understood. Since they suppress or inhibit the growth of certain microorganisms, it is assumed that such action relates directly or indirectly to this property.

The consumption of these compounds is capable of promoting the development of bacterial resistance in the animals' microbial population. Furthermore, it is known that such resistance can be transferred between bacteria. The significance of this phenomenon, as it may relate to the health of animals and man, has not been determined. In view of the potential threat from a buildup of multiple bacterial resistance, the Food and Drug Administration has proposed that the subtherapeutic use of certain antibacterial compounds in feed be restricted. Thus, it is important to recognize that approved usage of any feed additive is subject to change and that constraints on their use will vary among countries.

Detailed information on specific antimicrobial agents, levels of usage, and legal requirements for use may be found in the Feed Additive Compendium, published each year by the Miller Publishing Company, 2501 Wayzata Boulevard, Minneapolis, Minnesota 55440, and in the compendium of Medicating Ingredient Brochures, Plant Products Division, Canada Department of Agriculture, Ottawa, Canada.

For official information concerning Food and Drug Administration approval of antibiotics and other animal drugs, the *Code of Federal Regulations (CFR)*, Title 21, should be consulted. Title 21 is revised at least once each year as of April 1. The *CFR* is kept up to date by the individual issues of the *Federal Register*. These two publications must be used together to determine the latest version of any given rule. Title 21 is published in six parts: Part 500-599 covers animal drugs, feeds, and related products and is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 ($5.00). The *Federal Register* is available from the Superintendent of Documents ($50.00/year) and includes monthly issues of the *List of CFR Sections Affected* and *The Federal Register Index*.

NUTRIENT DEFICIENCIES AND DIETARY EXCESSES

Most diets of U.S. and Canadian swine are composed of one or more grains, together with soybean meal or other protein sources that complement the indispensable amino acids lacking in the grains. These major ingredients of the diet should be supplemented with vitamins and essential mineral elements to provide all the known nutrient requirements. Diets formulated in this manner should prevent the appearance of any signs of nutrient deficiencies or excesses when fed to swine reared under suitable environmental conditions and free from infectious diseases. Clinical signs (outwardly apparent) and subclinical signs (determinable only by clinical methodology) of nutrient deficiencies are presented in Table 1.

Dietary excesses, with readily recognizable clinical signs, seldom occur. They are nevertheless a potential problem, particularly with micronutrients such as the trace minerals and some nonnutrients. A toxicity of copper would not likely occur unless copper were added at a high level (250 ppm, or more), and with low dietary iron or zinc or high levels of calcium. Iron toxicity is less likely unless there is a vitamin E–selenium deficiency. Sodium chloride toxicity is avoided if adequate water is provided. Fluorosis is seldom seen unless all supplemental phosphorus is from a nondefluorinated raw rock phosphate source, but high levels of fluoride will reduce rate and efficiency of gain. Because of an interference with zinc absorption, an excess of calcium may be manifested by the skin condition, parakeratosis. Thus, signs of dietary excess are commonly conditioned by the interrelationship of two or more factors. Signs of these and other dietary excesses are presented in Table 2. The toxic dietary levels listed are those which experimentally produced the signs indicated and are not necessarily minimum toxic or maximum tolerant levels.

TABLE 1 Signs of Nutrient Deficiencies

	Signs of Nutrient Deficiency	
Nutrient	Clinical	Subclinical
Energy	Weakness, low body temperature, loss of weight, coma, and death	Hypoglycemia Loss of subcutaneous fat Elevated hematocrit and serum cholesterol Reduced blood glucose, calcium, and sodium
Protein: Amino acid	Impaired growth Unthriftiness Reduced resistance to bacterial infection	Kwashiorkor-like signs in baby pigs, including reduced serum protein and serum albumin, anemia, gross edema, and increased lipid liver concentration
Fat: Linoleic acid	Scaly dermatitis may appear	Small gallbladder Elevated triene/tetraene in tissue lipids
Vitamin A	Incoordination Lordosis Paralysis of rear limbs Night blindness Congenital defects	Retarded bone growth Increase in cerebrospinal fluid pressure Degeneration of sciatic and femoral nerves Minimal visual purple Atrophy of epithelial layers of genital tract

TABLE 1 *Continued*

Nutrient	Signs of Nutrient Deficiency: Clinical	Subclinical
Vitamin D	Rickets Osteomalacia Low calcium tetany	Lack of bone calcification and proliferation of epiphyseal cartilage Rib and vertebra fracture Low plasma calcium, magnesium, and inorganic phosphorus levels Elevated serum alkaline phosphatase levels
Vitamin E–Selenium	Edema Sudden death	Generalized edema Liver necrosis (hepatosis dietetica) Microangiopathy Cardiac muscle degeneration (mulberry heart) Pale, dystrophic muscle
Vitamin K	Pale newborn pigs with loss of blood from umbilical cord Sudden death following dicoumarin intake	Increased prothrombin time Increased blood-clotting time Internal hemorrhage Anemia due to blood loss
Thiamin	Poor appetite Poor growth Sudden death	Cardiac hypertrophy Bradycardia First and second degree auriculoventricular block Elevated plasma pyruvate
Riboflavin	Slow growth Seborrhea Impaired sow reproductivity	Lens cataracts Increase in neutrophilic leukocytes Birth of weak pigs with skeletal anomalies
Niacin	Poor appetite Poor growth Severe diarrhea Dermatitis	Necrotic lesions of intestine
Pantothenic acid	Poor appetite Poor growth Diarrhea Unusual gait (goose-stepping) Impaired sow reproductivity	Inflammation of colon Degeneration of sciatic and peripheral nerves Reduced blood pantothenic acid level Reduced free pantothenic acid level in milk
Vitamin B_6	Poor growth Epileptic seizures	Microcytic hypochromic anemia Elevated serum iron Fatty infiltration of liver Elevated urinary xanthurenic acid Elevated gamma globulin-like blood protein fraction
Vitamin B_{12}	Depressed growth Hypersensitivity Reduced sow reproductivity	Reduced serum and tissue B_{12} levels
Choline	Slow growth Reduced litter size	Fatty infiltration of liver Reduced conception rate
Biotin	Dermatosis Spasticity of hind legs	Reduced urinary biotin excretion
Folacin	Poor growth Weakness	Normocytic anemia
Calcium	Rickets Osteomalacia Low calcium tetany	Lack of bone calcification Bones easily fractured Low plasma calcium level Elevated serum inorganic phosphorus and alkaline phosphatase
Phosphorus	Poor growth Rickets Osteomalacia	Lack of bone calcification Bones easily fractured Low serum inorganic phosphorus level Elevated serum calcium and alkaline phosphatase Enlarged costochondral junction (beading)

TABLE 1 *Continued*

Nutrient	Signs of Nutrient Deficiency: Clinical	Subclinical
Magnesium	Poor growth Stepping syndrome Weakened carpo-metacarpo-phalangeal and tarso-metatarso-phalangeal joints Tetany	Low serum magnesium and calcium Reduced bone magnesium
Potassium	Anorexia Rough hair coat Emaciation Ataxia	Reduced heart rate Increased PR, QRS, and QT intervals on electrocardiogram Reduced serum potassium
Sodium	Poor appetite Low water consumption Unthriftiness	Negative sodium balance Elevated serum potassium Elevated plasma urea nitrogen Reduced chlorine retention
Chlorine	Poor growth	Reduced plasma chlorine Reduced sodium and potassium retention
Iron	Poor growth Rough hair coat Pallor Anoxia	Hypochromic microcytic anemia Enlarged heart and spleen Enlarged fatty liver Ascites Clumping of erythroblastic cells in bone marrow Reduced serum iron and percent transferrin saturation
Copper	Leg weakness Ataxia	Microcytic hypochromic anemia Reduced serum copper and ceruloplasmin Aortic rupture Cardiac hypertrophy
Zinc	Poor growth Poor appetite Parakeratosis	Reduced serum, tissue, and milk zinc Reduced serum albumin–globulin ratio Reduced serum alkaline phosphatase Reduced thymus weight Retarded testicular development Impaired reproductivity of sows
Iodine	Goiter Myxedema Sows farrow weak, hairless pigs	Enlarged hemorrhagic thyroid Hyperplasia of follicular epithelium of thyroid Reduced plasma protein-bound iodine
Manganese	Lameness in growing pigs Increased fat deposition in pregnant gilts with birth of weak pigs with poor sense of balance	Replacement of cancellous bone with fibrous tissue Early closure of distal epiphyseal plate Low serum manganese and alkaline phosphatase Negative manganese balance
Water	Poor appetite Dehydration Loss of body weight Possible salt poisoning Death	Elevated hematocrit Elevated plasma electrolytes Loss of temperature regulation Tissue dehydration

TABLE 2 Signs of Dietary Excesses

Nutrient	Toxic Dietary Level[a]	Age	Signs of Dietary Excess
Calcium	1% (with limited zinc)	Immature	Depressed appetite, reduced rate of gain, parakeratosis
	1% (with adequate zinc and limited phosphorus)	Immature	Reduced rate of gain and reduced bone strength
Copper	300–500 mg/kg (in absence of higher levels of dietary iron and zinc)[b]	Immature	Reduced growth, lower hemoglobin, icterus, and death[c]
Iodine	800 mg/kg	Immature	Depressed feed intake and rate of gain, lowered hemoglobin,[d] and eye lesions
Iron	5,000 mg/kg	Immature	Depressed feed intake and rate of gain, reduced serum inorganic phosphorus and femur ash, rickets[e]
Manganese	4,000 mg/kg	Immature	Depressed feed intake, reduced growth rate, stiffness, and stilted gait
Selenium	5–8 mg/kg[f]	Immature	Anorexia, hair loss, separation of hoof and skin at coronary band, degenerative changes in liver and kidney
	10 mg/kg	Breeding (sows)	Reduced conception; pigs small, weak or dead at birth
Sodium chloride and other sodium salts	1–8% (with severe water restriction)	All ages	Nervousness, weakness, staggering, epileptic seizures, paralysis and death
Zinc	2,000 mg/kg	Immature	Growth depression, arthritis, hemorrhage in axillary spaces, gastritis and enteritis
Arsenic	990 mg/kg	Immature	Poor growth, erythema, ataxia, posterior paralysis, quadraplegia and blindness; myelin degeneration of optic and peripheral nerves
Cadmium	50 mg/kg	Immature	Reduced gain and hematocrit
	150 mg/kg	Immature	Severe depression of gain and hematocrit
	450 mg/kg	Immature	Severe depression of gain and hematocrit and appearance of dermatitis
Cobalt	400 mg/kg	Immature	Anorexia, growth depression, stiff-legged, humped back, incoordination and muscle tremors, anemia[g]
Fluorine:			
Soluble fluorides	100 mg/kg	Mature	Mottled enamel, enamel hypoplasia, softening of teeth, osteomalacia, excessive loss of weight by lactating sows
Rock phosphate F	200 mg/kg	Mature	
Gossypol[h]	200 mg/kg	Immature	Muscular weakness, dyspnea, generalized edema, death; myocarditis, hepatitis, and nephritis
Lead	660 mg/kg	Immature	Squealing as if in pain, diarrhea, salivation, grinding of teeth, depressed appetite, reduced growth rate, muscular tremors, ataxia, increased respiratory rate, decreased heart rate, enlarged carpal joints, impaired vision, clonic seizures, death
Mercury	Single oral dose of 5 to 15 mg methyl mercury dicyandiamide per kilogram of body weight	Immature	Anorexia, bodyweight loss, central nervous system depression, weakness, gagging, vomiting, diarrhea, ataxia, cyanosis, muscular tremors, postural and gait abnormalities, polyuria
Nitrate	1,800 mg NO_3/kg	Immature	Growth depression, dyspnea and cyanosis, elevated methemoglobin, lymphocytosis, reduced serum vitamin A and E levels
Nitrite	400 mg NO_2/kg	Immature	

TABLE 2 *Continued*

Nutrient	Toxic Dietary Level[a]	Age	Signs of Dietary Excess
Urea	2.5%	Immature	Reduced feed intake and growth rate; increased plasma urea nitrogen level

[a] The toxic dietary levels listed are those that have experimentally produced the signs indicated and are not necessarily minimum toxic or maximum tolerant levels.
[b] In a few instances, a dietary level of 250 mg/kg has resulted in signs of excess.
[c] In some instances, 500 mg/kg of copper has been fed without icterus or death occurring.
[d] Anemia of iodine toxicity alleviated with supplemental iron.
[e] Rickets from excessive dietary iron alleviated by increasing dietary phosphorus.
[f] Selenium toxicity partially alleviated with arsenic.
[g] Cobalt toxicity alleviated by supplemental methionine, iron, zinc, and manganese.
[h] Gossypol toxicity alleviated by increasing dietary iron to equal the weight of free gossypol.

FORMULATING DIETS

Formulation of swine diets requires some understanding of nutrient requirements and of the feed ingredients available that can supply these nutrients. Tables 9–10 show the average composition of various ingredients and serve as guides in arriving at their relative values as nutrient sources. A summary of recommended requirements for energy and nutrients is given in Tables 5–8. These guides can be used to formulate nutritionally adequate and economically practical diets that, when fed at the recommended level, will allow optimum production.

From a nutritional standpoint, there is no one "best" formula in terms of ingredients that are used. Ingredients should therefore be selected on the basis of availability, price, and quality of the nutrients they contain. Corn, sorghum, barley, and wheat are the primary energy-supplying ingredients in the diet of swine of 5 kg liveweight or heavier. These grains are deficient in certain indispensable amino acids, inorganic elements, and vitamins. Soybean meal, some other oilseed meal, or animal protein meal are commonly used as sources of supplemental amino acids to the grain-based diets.

FORMULATING CORN–SOYBEAN MEAL DIETS ON THE BASIS OF LYSINE, PHOSPHORUS, AND CALCIUM CONTENT

In formulating swine diets utilizing corn and soybean meal, these two ingredients make up about 97 percent of the diet, with the remaining 3 percent comprised of carriers combined with one or more inorganic elements, vitamins, or antimicrobial compounds. Both corn and soybean meal are high and quite similar in metabolizable energy content. Thus, any combination of these two ingredients, comprising 97 percent of the diet, will result in a high-energy diet. The first step in formulation is presented in equation (1), in which C is the percent of corn in the diet and S is the percent of soybean meal.

$$\begin{aligned} C + S &= 97 \\ C &= 97 - S \end{aligned} \qquad (1)$$

Since lysine is the first limiting amino acid in corn–soybean meal diets, one can manipulate the proportions of corn and soybean meal to meet the required concentration of this amino acid and be confident that the requirements for all of the other indispensable amino acids will be met and that the level of dispensable amino acid nitrogen will also be adequate. For example, to formulate a corn–soybean meal diet for 25-kg liveweight pigs, one may use equation (2).

$$A \times S + B(97 - S) = L \times 100 \qquad (2)$$

A = % lysine in solvent extracted, 44% crude protein, soybean meal (5-04-604) = 2.93 (Table 10).
B = % lysine in yellow dent corn grain (4-02-935) = 0.24 (Table 10).
L = % lysine requirement of the diet of the 25-kg liveweight pig = 0.70 (Table 5).
S = % solvent extracted, 44% crude protein, soybean meal (5-04-604) in the diet.
$97 - S$ = % yellow dent corn grain (4-02-935) in the diet.

Equation (2) can now be written with only one unknown (S), and the percentages of corn and soybean meal in the diet easily solved.

$$\begin{aligned} 2.93S + 0.24(97 - S) &= 0.70 \times 100 \\ \%\ \text{soybean meal in diet} = S &= 17.4 \\ \%\ \text{corn in diet} = 97 - S &= 79.6 \end{aligned} \qquad (2')$$

The next step is to provide an ingredient that will supply inorganic phosphorus to complete the requirement for this element. If defluorinated phosphate (Table 11), which contains 18 percent phosphorus, is selected, equation (3) will solve for the percent of defluorinated phosphate (P) to incorporate into the diet.

$18P = 0.50^{*} \times 100 - [79.6 \times \%P \text{ in corn}^{\dagger} + 17.4 \times \%P \text{ in Soybean meal}^{\dagger}]$

$18P = 0.50 \times 100 - [79.6 \times 0.28 + 17.4 \times 0.65]$

$P = 0.9 = \%$ defluorinated phosphate in diet. (3)

The next step is to provide an ingredient that will supply calcium to complete the requirement for this element. If ground limestone (Table 11), which contains 38 percent calcium, is selected, equation (4) will solve for the percent of ground limestone (C) to include in the diet.

$38C = 0.60^{*} \times 100 - [79.6 \times \%Ca \text{ in corn}^{\dagger} + 17.4 \times \%Ca \text{ in soybean meal}^{\dagger} + 0.9 \times \%Ca \text{ in defl. phos.}^{\ddagger}]$

$38C = 0.60 \times 100 - [79.6 \times 0.02 + 17.4 \times 0.29 + 0.9 \times 32]$

$C = 0.65 = \%$ ground limestone in diet. (4)

Completing diet: Final fortification of the corn–soybean meal diet may be completed by supplying the following: 0.25% sodium chloride; a vitamin premix that will supply the vitamins that are likely limiting in a corn–soybean meal diet, including vitamins A, D, E, and perhaps K as well as riboflavin, niacin, pantothenic acid, choline, and vitamin B_{12}; a trace element premix including iron, zinc, iodine, manganese, copper, and selenium; and, if desired, a premix that contains one or more antimicrobial compounds. The complete diet then is:

Corn, dent yellow, grain 4-02-935	79.6%
Soybean meal, solvent 5-04-604	17.4%
Defluorinated phosphate	0.9%
Limestone, ground (38% Ca)	0.65%
Sodium chloride	0.25%
Vitamin premix	0.25%
Trace element premix	0.25%
Antimicrobial premix	0.25%
TOTAL	99.55%

This can be made to 100 percent by changing the amount of corn to 80.05 percent.

* Table 5
† Table 9
‡ Table 11

TABLE 3 Weight Equivalents

1 lb = 453.6 g = 0.4536 kg = 16 oz
1 oz = 28.35 g
1 kg = 1,000 g = 2.2046 lb
1 g = 1,000 mg
1 mg = 1,000 μg = 0.001 g
1 μg = 0.001 mg = 0.000001 g
1 μg per g or 1 mg per kg is the same as 1 ppm
0.3 μg vitamin A alcohol = 0.344 mg vitamin A acetate = 1.0 IU vitamin A
0.025 μg crystalline vitamin D_3 = 1.0 IU vitamin D_3
1 mg *dl*-α-tocopheryl acetate = 1.0 IU vitamin E
1 mg *dl*-α-tocopherol = 1.1 IU vitamin E
1 mg *d*-α-tocopherol = 1.49 IU vitamin E

TABLE 4 Weight-Unit Conversion Factors

Units Given	Units Wanted	For Conversion Multiply by
lb	g	453.6
lb	kg	0.4536
oz	g	28.35
kg	lb	2.2046
kg	mg	1,000,000
kg	g	1,000
g	mg	1,000
g	μg	1,000,000
mg	μg	1,000
mg/g	mg/lb	453.6
mg/kg	mg/lb	0.4536
μg/kg	μg/lb	0.4536
joule	kcal	0.239
kcal	joule	4.18
Mcal	kcal	1,000
kcal/kg	kcal/lb	0.4536
kcal/lb	kcal/kg	2.2046
ppm	μg/g	1
ppm	mg/kg	1
ppm	mg/lb	0.4536
mg/kg	%	0.0001
ppm	%	0.0001
mg/g	%	0.1
g/kg	%	0.1

TABLES OF NUTRIENT REQUIREMENTS

It is impossible to list dietary requirements that are applicable to all conditions and types of diets. The nutrient values set forth in Tables 5–8 are valid for some of the more common feeding conditions found in the United States and Canada. Requirements reflect the level of each nutrient needed for optimal performance when swine are fed a fortified grain–soybean meal diet supplying the recommended levels of energy and protein. Moreover, in Tables 5 and 6 liveweight range and expected level of performance are taken into consideration. Something less than 100 percent utilization of the nutrients from natural ingredients can be assumed. Therefore, the values listed are not absolute requirements. Furthermore, suggested requirements tend to be averages and do not represent a minimum as much as that quantity required for optimum performance. Where experimental data were lacking, estimates were made of the levels that, in practice, permit normal performance.

When swine are fed *ad libitum*, requirements expressed in terms of dietary concentration are generally most useful (Tables 5 and 7). Thus, while individual pigs within a pen possess characteristic variation in liveweight and growth potential, and hence have different absolute requirements, the amount of each nutrient needed, expressed as a percent of the diet, may be very similar. It can be assumed that the larger animal simply meets its requirements by consuming more feed. For gestation, where sows are generally fed restricted quantities of feed, daily requirements are most useful (Table 8). A similar situation may exist for boars and for lactating sows. A recent trend, for example, has been to specify requirements for lactation based upon the size of the litter being nursed.

Criteria of response can influence requirements markedly. For example, maximal carcass leanness may require greater concentrations of certain nutrients than maximal rate of gain. Lean pigs deposit more protein in their gain, which increases their requirements for protein and individual amino acids. Leanness is associated positively with feed efficiency; thus requirements for maximal feed efficiency are generally greater than those for maximal weight gain. Maximal blood hemoglobin concentration may necessitate higher levels of iron than those needed for maximal rate or efficiency of gain, and maximal bone ash generally requires higher levels of calcium and phosphorus than those needed for maximal weight gain. Ultimately, each swine manager must select a set of standards that will permit the greatest economic return in the particular environment. Optimum standards will relate to the genetic potential of the herd and to the price and availability of feed ingredients in the region.

TABLE 5 Nutrient Requirements of Growing-Finishing Swine Fed *Ad Libitum*: Percent or Amount per Kilogram of Diet[a]

Liveweight (kg)		1–5[a]	5–10	10–20	20–35	35–60	60–100
Expected Daily Gain (g)		200	300	500	600	700	800
Expected Efficiency (g gain/kg feed)		800	600	500	400	350	270
Expected Efficiency (feed/gain)		1.25	1.67	2.00	2.50	2.86	3.75
Digestible energy[b]	kcal	3,700	3,500	3,370	3,380	3,390	3,395
Metabolizable energy[b]	kcal	3,600	3,400	3,160	3,175	3,190	3,195
Crude protein[c]	%	27	20	18	16	14	13
Indispensable amino acids							
Lysine	%	1.28	0.95	0.79	0.70	0.61	0.57
Arginine	%	0.33	0.25	0.23	0.20	0.18	0.16
Histidine	%	0.31	0.23	0.20	0.18	0.16	0.15
Isoleucine	%	0.85	0.63	0.56	0.50	0.44	0.41
Leucine	%	1.01	0.75	0.68	0.60	0.52	0.48
Methionine + cystine[d]	%	0.76	0.56	0.51	0.45	0.40	0.30
Phenylalanine + tyrosine[e]	%	1.18	0.88	0.79	0.70	0.61	0.57
Threonine	%	0.76	0.56	0.51	0.45	0.39	0.37
Tryptophan[f]	%	0.20	0.15	0.13	0.12	0.11	0.10
Valine	%	0.85	0.63	0.56	0.50	0.44	0.41
Mineral elements							
Calcium	%	0.90	0.80	0.65	0.60	0.55	0.50
Phosphorus[g]	%	0.70	0.60	0.55	0.50	0.45	0.40
Sodium	%	0.10	0.10	0.10	0.10	0.10	0.10
Chlorine	%	0.13	0.13	0.13	0.13	0.13	0.13
Potassium	%	0.30	0.26	0.26	0.23	0.20	0.17
Magnesium	%	0.04	0.04	0.04	0.04	0.04	0.04
Iron	mg	150	140	80	60	50	40
Zinc	mg	100	100	80	60	50	50
Manganese	mg	4.0	4.0	3.0	2.0	2.0	2.0
Copper	mg	6.0	6.0	5.0	4.0	3.0	3.0
Iodine	mg	0.14	0.14	0.14	0.14	0.14	0.14
Selenium	mg	0.15	0.15	0.15	0.15	0.15	0.10
Vitamins							
Vitamin A	IU	2,200	2,200	1,750	1,300	1,300	1,300
or β-carotene	mg	8.8	8.8	7.0	5.2	5.2	5.2
Vitamin D	IU	220	220	200	200	150	125
Vitamin E	IU	11	11	11	11	11	11
Vitamin K (menadione)	mg	2.0	2.0	2.0	2.0	2.0	2.0
Riboflavin	mg	3.0	3.0	3.0	2.6	2.2	2.2
Niacin[h]	mg	22	22	18	14	12	10
Pantothenic acid	mg	13	13	11	11	11	11
Vitamin B_{12}	μg	22	22	15	11	11	11
Choline[i]	mg	1,100	1,100	900	700	550	400
Thiamin	mg	1.3	1.3	1.1	1.1	1.1	1.1
Vitamin B_6	mg	1.5	1.5	1.5	1.1	1.1	1.1
Biotin[j]	mg	0.10	0.10	0.10	0.10	0.10	0.10
Folacin[j]	mg	0.60	0.60	0.60	0.60	0.60	0.60

[a] Requirements reflect the estimated levels of each nutrient needed for optimal performance when a fortified grain–soybean meal diet is fed, except that a substantial level of milk products should be included in the diet of the 1–5-kg pig. Concentrations are based upon amounts per unit of air-dry diet (i.e., 90 percent dry matter).

[b] These are not absolute requirements but are suggested energy levels derived from diets containing corn and soybean meal (44 percent crude protein). When lower energy grains are fed, these energy levels will not be met; consequently, feed efficiency would be lowered.

[c] Approximate protein levels required to meet the need for indispensable amino acids when a fortified grain–soybean meal diet is fed to pigs weighing more than 5 kg.

[d] Methionine can fulfill the total requirement; cystine can meet at least 50 percent of the total requirement.

[e] Phenylalanine can fulfill the total requirement; tyrosine can meet at least 50 percent of the total requirement.

[f] It is assumed that usable tryptophan content of corn does not exceed 0.05 percent.

[g] At least 30 percent of the phosphorus requirement should be provided by inorganic and/or animal product sources.

[h] It is assumed that most of the niacin present in cereal grains and their by-products is in bound form and thus unavailable to swine. The niacin contributed by these sources is not included in the requirement listed. In excess of its requirement for protein synthesis, tryptophan can be converted to niacin (50 mg tryptophan yields 1 mg niacin).

[i] In excess of its requirement for protein synthesis, methionine can spare dietary choline (4.3 mg methionine is equal in methylating capacity to 1 mg choline).

[j] These levels are suggested. No requirements have been established.

TABLE 6 Daily Nutrient Requirements of Growing–Finishing Swine Fed *Ad Libitum*[a]

Liveweight (kg) Air-Dry Feed Intake (g)		1–5[a] 250	5–10 500	10–20 1,000	20–35 1,500	35–60 2,000	60–100 3,000
Digestible energy[b]	kcal	925	1,750	3,370	5,055	6,740	10,110
Metabolizable energy[b]	kcal	900	1,700	3,160	4,740	6,320	9,480
Crude protein[c]	g	67.5	100	180	240	280	390
Indispensable amino acids							
Lysine	g	3.2	4.8	7.9	10.5	12.2	17.1
Arginine	g	0.8	1.3	2.3	3.0	3.6	4.8
Histidine	g	0.8	1.2	2.0	2.7	3.2	4.5
Isoleucine	g	2.1	3.2	5.6	7.5	8.8	12.3
Leucine	g	2.5	3.8	6.8	9.0	10.4	14.4
Methionine + cystine[d]	g	1.9	2.8	5.1	6.8	8.0	9.0
Phenylalanine + tyrosine[e]	g	3.0	4.4	7.9	10.5	12.2	17.1
Threonine	g	1.9	2.8	5.1	6.8	7.8	11.1
Tryptophan[f]	g	0.5	0.8	1.3	1.8	2.2	3.0
Valine	g	2.1	3.2	5.6	7.5	8.8	12.3
Mineral elements							
Calcium	g	2.3	4.0	6.5	9.0	11.0	15.0
Phosphorus[g]	g	1.8	3.0	5.5	7.5	9.0	12.0
Sodium	g	0.25	0.5	1.0	1.5	2.0	3.0
Chlorine	g	0.33	0.7	1.3	2.0	2.6	3.9
Potassium	g	0.75	1.3	2.6	3.5	4.0	5.1
Magnesium	g	0.10	0.2	0.4	0.6	0.8	1.2
Iron	mg	38	70	80	90	100	120
Zinc	mg	25	50	80	90	100	150
Manganese	mg	1.0	2	3	3	4	6
Copper	mg	1.5	3	5	6	6	9
Iodine	mg	0.04	0.07	0.14	0.21	0.28	0.42
Selenium	mg	0.04	0.08	0.15	0.22	0.30	0.30
Vitamins							
Vitamin A	IU	550	1,100	1,750	1,950	2,600	3,900
or β-carotene	mg	2.2	4.4	7.0	7.8	10.4	15.6
Vitamin D	IU	55	110	200	300	300	375
Vitamin E	IU	2.8	5.5	11	17	22	33
Vitamin K (menadione)	mg	0.50	1.1	2.2	3.3	4.4	6
Riboflavin	mg	0.75	1.5	3.0	3.9	4.4	7
Niacin[h]	mg	5.5	11	18	21	24	30
Pantothenic acid	mg	3.3	6.5	11	17	22	33
Vitamin B_{12}	μg	5.5	11	15	17	22	33
Choline[i]	mg	275	550	900	1,050	1,100	1,200
Thiamin	mg	0.33	0.65	1.1	1.7	2.2	3.3
Vitamin B_6	mg	0.38	0.75	1.5	1.7	2.2	3.3
Biotin[j]	mg	0.03	0.05	0.10	0.15	0.20	0.30
Folacin[j]	mg	0.15	0.30	0.60	0.90	1.2	1.8

[a] Requirements reflect the estimated levels of each nutrient needed for optimal performance when a fortified grain–soybean meal diet is fed, except that a substantial level of milk products should be included in the diet of the 1–5-kg pig. Concentrations are based upon amounts per unit of air-dry diet (i.e., 90 percent dry matter).

[b] These are not absolute requirements, but are suggested energy levels derived from diets containing corn and soybean meal (44 percent crude protein). When lower energy grains are fed, these energy levels will not be met; consequently, feed efficiency would be lowered.

[c] Approximate protein levels required to meet the need for indispensable amino acids when a fortified grain–soybean meal diet is fed to pigs weighing more than 5 kg.

[d] Methionine can fulfill the total requirement; cystine can meet at least 50 percent of the total requirement.

[e] Phenylalanine can fulfill the total requirement; tryosine can meet at least 50 percent of the total requirement.

[f] It is assumed that usable tryptophan content of corn does not exceed 0.05 percent.

[g] At least 30 percent of the phosphorus requirement should be provided by inorganic and/or animal product sources.

[h] It is assumed that most of the niacin present in cereal grains and their by-products is in bound form and thus unavailable to swine. The niacin contributed by these sources is not included in the requirement listed. In excess of its requirement for protein synthesis, tryptophan can be converted to niacin (50 mg tryptophan yields 1 mg niacin).

[i] In excess of its requirement for protein synthesis, methionine can spare dietary choline (4.3 mg methionine is equal in methylating capacity to 1 mg choline).

[j] These levels are suggested. No requirements have been established.

TABLE 7 Nutrient Requirements of Breeding Swine: Percent or Amount per Kilogram of Diet[a]

		Bred Gilts and Sows; Young and Adult Boars[b]	Lactating Gilts and Sows
Digestible energy	kcal	3,400	3,395
Metabolizable energy	kcal	3,200	3,195
Crude protein[c]	%	12	13
Indispensable amino acids			
Arginine	%	0	0.40
Histidine	%	0.15	0.25
Isoleucine	%	0.37	0.39
Leucine	%	0.42	0.70
Lysine	%	0.43	0.58
Methionine + cystine[d]	%	0.23	0.36
Phenylalanine + tyrosine[e]	%	0.52	0.85
Threonine	%	0.34	0.43
Tryptophan[f]	%	0.09	0.12
Valine	%	0.46	0.55
Mineral elements			
Calcium	%	0.75	0.75
Phosphorus[g]	%	0.60	0.50
Sodium	%	0.15	0.20
Chlorine	%	0.25	0.30
Potassium	%	0.20	0.20
Magnesium	%	0.04	0.04
Iron	mg	80	80
Zinc	mg	50	50
Manganese	mg	10	10
Copper	mg	5	5
Iodine	mg	0.14	0.14
Selenium	mg	0.15	0.15
Vitamins			
Vitamin A	IU	4,000	2,000
or β-carotene	mg	16	8
Vitamin D	IU	200	200
Vitamin E	IU	10	10
Vitamin K (menadione)	mg	2	2
Riboflavin	mg	3	3
Niacin[h]	mg	10	10
Pantothenic acid	mg	12	12
Vitamin B_{12}	μg	15	15
Choline	mg	1,250	1,250
Thiamin	mg	1	1
Vitamin B_6	mg	1	1
Biotin[i]	mg	0.1	0.1
Folacin[i]	mg	0.6	0.6

[a] Requirements reflect the estimated levels of each nutrient needed for optimal performance when a fortified grain-soybean meal diet is fed. Concentrations are based upon amounts per unit of air-dry diet (i.e., 90 percent dry matter).

[b] Requirements for boars of breeding age have not been established. It is suggested that the requirements will not differ significantly from that of bred gilts and sows.

[c] Approximate protein levels required to meet the need for indispensable amino acids when a fortified grain-soybean meal diet is fed. The true digestibilities of the amino acids were assumed to be 90 percent.

[d] Methionine can fulfill the total requirement; cystine can meet at least 50 percent of the total requirement.

[e] Phenylalanine can fulfill the total requirement; tyrosine can meet at least 50 percent of the total requirement.

[f] It is assumed that usable tryptophan content of corn does not exceed 0.05 percent.

[g] At least 30 percent of the phosphorus requirement should be provided by inorganic and/or animal product sources.

[h] It is assumed that most of the niacin present in cereal grains and their by-products is in bound form and thus unavailable to swine. The niacin contributed by these sources is not included in the requirement listed. In excess of its requirement for protein synthesis, tryptophan can be converted to niacin (50 mg tryptophan yields 1 mg niacin).

[i] These levels are suggested. No requirements have been established.

TABLE 8 Daily Nutrient Requirements of Breeding Swine[a]

		Bred Gilts And Sows; Young and Adult Boars	Lactating Gilts and Sows		
Air-Dry Feed Intake (g)		1,800[b]	4,000	4,750	5,500
Digestible energy	kcal	6,120[c]	13,580	16,130	18,670
Metabolizable energy	kcal	5,760[c]	12,780	15,180	17,570
Crude protein	g	216	520	618	715
Indispensable amino acids					
Arginine	g	0	16.0	19.0	22.0
Histidine	g	2.7	10.0	11.9	13.8
Isoleucine	g	6.7	15.6	18.5	21.4
Leucine	g	7.6	28.0	33.2	38.5
Lysine	g	7.7	23.2	27.6	31.9
Methionine + cystine[d]	g	4.1	14.4	17.1	19.8
Phenylalanine + tyrosine[e]	g	9.4	34.0	40.4	46.8
Threonine	g	6.1	17.2	20.4	23.6
Tryptophan[f]	g	1.6	4.8	5.7	6.6
Valine	g	8.3	22.0	26.1	30.2
Mineral elements					
Calcium	g	13.5	30.0	35.6	41.2
Phosphorus[g]	g	10.8	20.0	23.8	27.5
Sodium	g	2.7	8.0	9.5	11.0
Chlorine	g	4.5	12.0	14.2	16.5
Potassium	g	3.6	8.0	9.5	11.0
Magnesium	g	0.7	1.6	1.9	2.2
Iron	mg	144	320	380	440
Zinc	mg	90	200	238	275
Manganese	mg	18	40	48	55
Copper	mg	9	20	24	28
Iodine	mg	0.25	0.56	0.66	0.77
Selenium	mg	0.27	0.40	0.48	0.55
Vitamins					
Vitamin A	IU	7,200	8,000	9,500	11,000
or β-carotene	mg	28.8	32.0	38.0	44.0
Vitamin D	IU	360	800	950	1,100
Vitamin E	IU	18.0	40.0	47.5	55.0
Vitamin K	mg	3.6	8.0	9.5	11.0
Riboflavin	mg	5.4	12.0	14.2	16.5
Niacin[h]	mg	18.0	40.0	47.5	55.0
Pantothenic acid	mg	21.6	48.0	57.0	66.0
Vitamin B_{12}	μg	27.0	60.0	71.2	82.5
Choline	mg	2,250.0	5,000.0	5,940.0	6,875.0
Thiamin	mg	1.8	4.0	4.8	5.5
Vitamin B_6	mg	1.8	4.0	4.8	5.5
Biotin[i]	mg	0.18	0.4	0.48	0.55
Folacin[i]	mg	1.08	2.4	2.8	3.3

[a] Requirements reflect the estimated levels of each nutrient needed for optimal performance when a fortified grain–soybean meal diet is fed. Concentrations are based upon amounts per unit of air-dry diet (i.e., 90 percent dry matter).
[b] An additional 25 percent should be fed to working boars.
[c] Individual feeding and moderate climatic conditions are assumed. An energy reduction of about 10 percent is possible when gilts and sows are tethered or individually penned in a stall in environmentally controlled housing. An energy increase of about 25 percent is suggested for cold climatic (winter) conditions.
[d] Methionine can fulfill the total requirement; cystine can meet at least 50 percent of the total requirement.
[e] Phenylalanine can fulfill the total requirement; tyrosine can meet at least 50 percent of the total requirement.
[f] It is assumed that usable tryptophan content of corn does not exceed 0.05 percent.
[g] At least 30 percent of the phosphorus requirement should be provided by inorganic and/or animal product sources.
[h] It is assumed that most of the niacin present in cereal grains and their by-products is in bound form and thus unavailable to swine. The niacin contributed by these sources is not included in the requirement listed. In excess of its requirement for protein synthesis, tryptophan can be converted to niacin (50 mg tryptophan yields 1 mg niacin).
[i] These levels are suggested. No requirements have been established.

COMPOSITION OF FEEDS AND MINERAL SOURCES

In formulating diets to meet the recommended nutrient requirements of swine, it is necessary to know the nutrient composition and the bioavailability of nutrients in each ingredient used. Tables 9 and 10 give the composition of ingredients commonly used in swine diets. Values in the tables have been compiled from several National Academy of Sciences–National Research Council reports.* Data were also obtained from the International Feedstuffs Institute, Utah State University,† the Subcommittee on Feed Composition of the NRC Committee on Animal Nutrition,‡ and from individuals at universities, agricultural experiment stations, commercial feed companies, and the *Feedstuffs Yearbook*, Volume 48 (1976).

Individual ingredients may vary widely in composition because of the variation in species or variety, storage conditions, climate, soil moisture, and nutrient status. Variations in analytical procedures also affect values obtained. Therefore, the values given are an average and are subject to interpretation.

In the previous edition, the names of feed ingredients included considerable detail as to how the ingredient was processed and the grade or quality. In this edition, short ingredient names are listed and only those commonly used in swine feeding are included. A six-digit International Feed Number is given for each ingredient. The first digit is the class designation.§ In computer formulation this reference number may be used as the "numerical name" of an ingredient. This number is also listed after each Official Feed Definition in the Association of American Feed Control Officials *Handbook*.‖ Nutrient content is expressed on an "as fed" or "as is" basis. For weight-unit conversion factors and weight equivalents see Tables 3 and 4.

In addition to feedstuffs composition, the sources and composition of minerals frequently fed to swine are listed in Table 11. The percentage of the mineral in each mineral source is given for the pure compound. The percent purity for technical and feed grade sources should, therefore, be multiplied by the listed percentage in this table to arrive at the percent of the element in the source being used.

Abbreviations for Terms Used in Tables 9 and 10	
DE	digestible energy
dehy	dehydrated
kcal	kilocalories
kg	kilogram(s)
ME	metabolizable energy
w	with

* *Atlas of Nutritional Data on United States and Canadian Feeds, 1971.* ISBN 0-309-01919-2.
United States–Canadian Tables of Feed Composition, 1969. ISBN 0-309-01684-3.
Nutrient Requirements of Poultry, 1977. ISBN 0-309-02725-X.
Nutrient Requirements of Swine, 1973. ISBN 0-309-02140-5.

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§ 1. Dry forages and roughages
2. Pasture, range plants, and forages fed green
3. Silages
4. Energy feeds
5. Protein supplements
6. Minerals
7. Vitamins
8. Additives

‖ Epps, Ernest A., Jr., Division of Agricultural Chemistry, P.O. Box 16390-A, Baton Rouge, Louisiana 70803.

TABLE 9 Average Composition of Some Feed Ingredients Commonly Used in Swine Diets (Excluding Amino Acids)[a]

Line No.		International Feed Number[b]	Dry Matter (%)	Energy (kcal/kg)		Protein (%)	Ether Extract (%)	Crude Fiber (%)	Minerals			
				DE	ME				Calcium (%)	Phosphorus (%)	Potassium (%)	Chlorine (%)
01	Alfalfa meal, dehy., 17% protein	1-00-023	92	2580	2270	17.5	2.5	24.1	1.44	0.22	2.40	0.46
02	Barley	4-00-549	89	3086	2870	11.6	1.8	5.1	0.05	0.36	0.48	0.15
03	Barley, Pacific Coast	4-07-939	89	3130	2940	9.0	2.0	6.4	0.05	0.32	0.53	0.15
04	Beans, field (*Vicia faba*)	5-09-262	89	3263	3080	26.0	1.4	8.2	0.14	0.54	1.20	—
05	Beet pulp, dried	4-00-669	91	2866	2345	8.0	0.5	21.0	0.60	0.10	0.21	—
06	Blood meal, spray or ring dried	5-00-381	86	2690	1927	85.0	1.0	0.6	0.30	0.25	0.90	0.27
07	Brewers dried grains	5-02-141	92	1940	1710	25.3	6.2	15.3	0.29	0.52	0.09	0.12
08	Corn, dent yellow, grain	4-02-935	89	3525	3325	8.8	3.8	2.2	0.02	0.28	0.30	0.04
09	Corn and cob meal	4-02-849	85	3086	2500	7.8	3.0	10.0	0.04	0.21	0.45	0.04
10	Corn, gluten feed	5-02-903	90	3307	2400	22.0	2.5	10.0	0.40	0.80	0.57	0.22
11	gluten meal, 41%	5-02-411	91	3230	3069	41.0	2.5	4.0	0.23	0.55	0.31	0.11
12	Corn, distillers grain w/solubles, dehy.	5-02-843	93	3568	3390	27.2	9.0	9.1	0.35	0.95	1.00	0.17
13	Corn, distillers solubles, dehy.	5-02-844	92	3307	2900	28.5	9.0	4.0	0.35	1.33	1.75	0.26
14	Corn, hominy feed	4-02-887	90	3615	3365	10.0	6.9	6.0	0.04	0.50	0.67	0.05
15	Cottonseed meal, mechanical extracted	5-01-609	93	2954	2453	40.9	3.9	12.6	0.17	1.05	1.19	0.04
16	Cottonseed meal, solvent extracted	5-01-619	92	2689	2555	41.4	1.5	11.3	0.15	0.97	1.22	0.03
17	Feather meal	5-03-795	93	2778	2270	86.4	3.3	1.0	0.20	0.80	0.31	—
18	Fish meal, anchovy	5-01-985	92	3086	2450	64.2	10.0	1.0	3.73	2.43	0.90	0.29
19	herring	5-02-000	93	3086	2500	72.3	10.0	0.7	2.29	1.70	1.50	0.90
20	Menhaden	5-02-009	92	2734	2230	60.5	9.4	0.7	5.11	2.88	0.77	0.60
21	Fish solubles, condensed	5-01-969	51	3307	3190	31.5	4.0	0.2	0.30	0.50	1.74	2.65
22	Meat and bone meal, 50%	5-09-322	93	2866	2434	50.4	8.6	2.8	10.10	4.96	1.40	0.74
23	Meat meal, 55%	5-09-323	92	2998	2540	54.4	7.1	2.5	8.27	4.10	1.40	0.91
24	Molasses, beet	4-00-668	79	2460	2320	6.1	0.0	0.0	0.13	0.06	4.83	1.30
25	Molasses, cane	4-04-696	74	2469	2343	2.9	0.0	0.0	0.82	0.08	2.38	—
26	Oats	4-03-309	89	2866	2668	11.4	4.2	10.8	0.06	0.27	0.37	0.11
27	Oat groats (dehulled oats)	4-03-331	91	3690	3400	16.0	5.5	3.0	0.07	0.43	0.34	—
28	Peas	5-03-600	90	3527	3200	23.8	1.3	5.5	0.11	0.42	1.02	0.06
29	Peanut meal, expeller	5-03-649	90	3600	3200	45.0	7.3	12.0	0.16	0.55	1.12	0.03
30	Peanut meal, solvent	5-03-650	90	2845	2920	47.0	1.2	13.1	0.20	0.65	1.15	—
31	Rapeseed meal, solvent	5-03-871	94	2998	2670	35.0	1.8	12.4	0.66	1.09	0.80	—
32	Rice bran, solvent	4-03-930	91	3080	2200	12.9	0.6	11.4	0.07	1.50	1.35	0.07
33	Rice, broken	4-03-932	89	2513	2360	8.7	1.7	9.8	0.08	—	—	0.08
34	Rice, polishings	4-03-943	90	3792	3000	12.2	11.0	4.1	0.05	1.31	1.06	0.11
35	Rye, grain	4-04-047	89	3307	2712	12.6	1.8	2.8	0.08	0.30	0.46	—
36	Safflower meal, solvent	5-04-110	91	2960	2435	28.5	0.5	30.6	0.40	1.10	0.80	—
37	Sesame meal, expeller	5-04-220	93	3130	2560	42.0	7.0	6.5	1.99	1.37	1.20	0.06
38	Skim milk, dried	5-01-175	92	3792	3360	33.5	0.9	0.0	1.28	1.02	1.59	0.50
39	Sorghum, grain (Milo)	4-04-444	89	3439	3229	8.9	2.8	2.3	0.03	0.28	0.32	0.09
40	Soybeans, full-fat cooked	5-04-597	90	4056	3540	37.0	18.0	5.5	0.25	0.58	1.61	0.03
41	Soybean meal, dehulled, solvent	5-04-612	90	3860	3485	48.5	1.0	3.9	0.27	0.62	2.02	0.05
42	Soybean meal, expeller	5-04-600	90	3483	2990	42.6	4.0	6.2	0.27	0.61	1.83	0.07
43	Soybean meal, solvent	5-04-604	89	3350	3090	44.0	0.8	7.3	0.29	0.65	2.00	0.05
44	Sunflower meal, dehulled, solvent	5-04-739	93	2998	2605	42.0	2.9	12.2	0.37	1.00	1.00	0.10
45	Wheat bran	4-05-190	90	2513	2320	15.7	4.0	11.0	0.14	1.15	1.19	0.06
46	Wheat shorts	4-05-201	89	3175	2910	16.8	4.2	8.2	0.11	0.76	0.88	0.07
47	Wheat middlings	4-05-205	88	3050	2940	16.0	3.0	7.0	0.12	0.90	0.60	0.03
48	Wheat, hard, red winter	4-05-268	87	3483	3220	14.1	1.9	2.4	0.05	0.37	0.45	0.05
49	Wheat, soft, red winter	4-05-294	86	3659	3416	10.2	1.8	2.4	0.05	0.31	0.40	0.08
50	Whey, dried	4-01-182	93	3439	3190	13.6	0.8	1.3	0.97	0.76	1.05	1.50
51	Whey, low lactose	4-01-186	91	3307	2750	15.5	1.0	0.3	1.95	0.98	3.00	2.10
52	Yeast, brewers dried	7-05-527	93	3135	2707	44.4	1.0	2.7	0.12	1.40	1.70	0.12

[a] As fed basis.

[b] The first digit is the feed class, coded as follows: (1) dry forages and roughages; (2) pasture, range plants and forages fed green; (3) silages; (4) energy feeds; and (5) protein supplements.

Line No.	Magnesium (%)	Sodium (%)	Sulfur (%)	Copper (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Vitamins: Biotin (mg/kg)	Choline (mg/kg)	Folacin (mg/kg)	Niacin (mg/kg)	Pantothenic Acid (mg/kg)	Pyridoxine (mg/kg)	Riboflavin (mg/kg)	Thiamin (mg/kg)	Vitamin B_{12} (mg/kg)	Vitamin E (IU/kg)
01	0.26	0.08	0.21	8.2	310	28.0	0.60	17	0.30	1097	6.3	38	28.4	6.5	15.7	3.4	0.004	125
02	0.14	0.04	0.15	7.5	50	8.0	0.10	17	0.08	990	0.5	63	9.2	3.0	1.2	4.0	—	36
03	0.12	0.02	—	7.7	60	16.3	0.10	15	0.15	1034	0.5	48	7.0	2.9	1.6	5.5	—	36
04	0.13	0.80	—	4.1	70	8.4	—	42	0.09	1670	—	22	3.0	—	1.6	5.5	—	1
05	0.27	0.32	0.20	12.5	300	35.0	—	0.7	—	800	—	20	0.8	—	1.1	0.2	—	—
06	0.22	0.33	0.32	8.1	3000	6.4	—	306	0.30	749	0.3	22	1.1	4.4	1.3	0.5	0.440	—
07	0.16	0.15	0.31	21.1	250	37.8	0.70	98	0.96	1723	7.1	29	8.0	0.7	1.4	0.5	—	25
08	0.12	0.02	0.08	3.4	35	5.0	0.04	10	0.11	530	0.2	34	7.5	7.0	1.0	3.5	—	22
09	0.13	0.01	0.18	6.7	70	7.7	0.07	9	0.05	393	0.3	17	4.0	5.0	0.9	—	—	19
10	0.29	0.95	0.22	47.9	460	23.8	0.10	48	0.33	1518	0.3	66	17.0	15.0	2.4	2.0	—	15
11	0.05	0.07	0.40	28.3	400	8.9	1.00	20	0.18	330	0.2	50	10.0	7.9	1.7	0.2	—	20
12	0.35	0.90	0.30	44.7	280	30.0	0.39	80	0.30	3400	0.9	80	11.0	2.2	8.6	3.5	—	40
13	0.64	0.26	0.37	82.7	560	73.7	0.33	85	1.40	4842	1.1	116	21.0	10.0	11.6	6.9	—	55
14	0.24	0.10	0.03	13.3	70	14.5	—	3	0.13	1500	0.3	46	8.0	11.0	2.2	7.9	—	—
15	0.42	0.04	0.40	18.6	160	22.9	0.90	57	0.60	2753	2.7	38	7.7	5.3	4.2	9.7	—	15
16	0.40	0.04	—	17.8	110	20.2	—	—	0.55	2933	2.7	40	9.9	3.0	4.0	7.7	—	15
17	0.20	0.71	—	—	—	21.0	—	—	0.04	891	0.2	27	10.0	—	2.1	0.1	0.600	—
18	0.24	1.10	0.54	9.3	220	9.5	1.36	103	0.23	5100	0.2	135	20.0	4.0	7.1	0.1	0.352	6
19	0.15	0.61	0.69	4.5	80	4.7	1.93	132	0.20	5306	0.5	142	22.0	4.0	9.9	0.1	0.588	17
20	0.16	0.41	0.45	10.8	440	33.0	2.10	147	0.15	3056	1.0	55	9.0	4.0	4.9	0.2	0.150	7
21	0.02	3.10	0.12	44.9	30	14.4	2.00	38	0.18	4028	—	169	35.0	12.2	14.6	5.5	0.347	—
22	1.12	0.72	0.26	1.5	490	14.2	0.25	93	0.14	1996	0.6	46	4.1	12.8	4.4	0.2	0.070	0.8
23	1.13	0.73	0.26	1.5	440	12.3	0.25	103	0.14	2077	0.6	57	5.0	3.0	5.5	0.2	—	0.8
24	0.23	—	0.48	17.7	70	4.7	—	14	0.70	880	—	48	4.0	—	2.1	—	—	4.4
25	0.35	0.90	0.35	59.6	200	42.2	—	—	0.70	660	—	45	39.0	—	2.3	0.9	—	4.4
26	0.16	0.06	0.21	5.9	70	43.2	0.30	1	0.30	1100	0.4	15	29.2	1.0	1.1	6.0	—	20.0
27	0.09	—	0.20	6.4	90	28.6	—	—	0.20	1232	0.3	18	11.0	—	1.3	6.8	—	15.0
28	—	0.04	—	—	50	—	—	30	0.18	642	0.4	17	4.6	1.0	0.8	1.8	—	—
29	0.32	—	0.28	—	—	24.8	—	—	0.39	1640	—	165	46.8	—	5.1	7.1	—	2.9
30	0.40	0.10	—	—	—	29.9	—	—	0.39	1980	—	165	50.6	—	11.0	6.6	—	3.0
31	0.51	0.50	—	7.0	180	43.0	0.98	66	—	6464	—	153	9.0	7.0	3.7	1.7	—	19.1
32	0.95	0.07	0.18	13.0	190	138.0	—	30	4.20	1135	—	293	23.0	14.0	2.5	22.5	—	59.8
33	0.11	0.07	0.06	—	—	18.0	—	17	0.08	800	0.2	46	8.0	—	0.7	—	—	14.5
34	0.65	0.10	0.17	—	160	—	—	—	0.61	1237	—	520	47.0	—	1.8	19.8	—	90.0
35	0.12	0.02	0.15	7.8	100	66.9	—	31	0.60	—	0.6	16	9.2	—	1.5	4.4	—	15.0
36	0.37	0.06	—	10.8	560	19.8	—	44	1.56	2247	0.5	60	43.8	—	11.3	2.8	—	0.9
37	0.86	0.04	0.43	—	—	47.9	—	100	0.34	1690	—	30	6.0	12.5	3.6	2.8	—	—
38	0.11	0.44	0.31	11.5	50	2.0	0.12	40	0.33	1250	0.6	12	33.0	3.9	22.0	3.5	0.010	9.1
39	0.20	0.01	0.09	14.1	40	12.9	—	14	0.09	678	0.2	41	12.0	3.2	1.1	4.0	—	12.0
40	0.21	0.28	0.22	15.8	80	29.8	0.11	16	0.27	2420	3.5	22	15.6	10.8	2.6	6.6	—	0.9
41	0.27	0.34	0.43	36.3	120	27.5	0.10	45	0.32	2850	0.7	22	15.0	5.0	2.9	1.7	—	3.3
42	0.26	0.27	0.33	18.0	140	30.7	0.10	60	0.33	2703	0.5	37	14.0	—	3.7	1.7	—	6.1
43	0.27	0.34	0.43	36.3	120	29.3	0.10	27	0.32	2794	0.5	60	13.3	8.0	2.9	1.7	—	2.1
44	0.75	2.00	—	3.5	30	22.9	—	—	1.45	2894	—	220	10.0	16.0	3.1	—	—	11.0
45	0.52	0.05	0.22	10.2	170	100.0	0.50	95	0.10	980	1.8	321	31.0	7.0	3.1	8.0	—	10.8
46	0.26	0.07	0.23	12.1	100	115.0	0.50	106	0.10	930	1.4	100	17.6	11.0	2.0	19.9	—	29.9
47	0.29	0.60	0.16	4.4	40	43.0	0.80	64	0.10	1100	0.6	53	13.0	9.0	2.2	18.9	—	—
48	0.17	0.04	0.12	10.6	50	62.2	0.06	14	0.04	1090	0.4	56	13.5	3.4	1.4	4.5	—	12.6
49	0.10	0.04	0.12	9.7	40	51.3	0.06	14	0.04	788	0.4	48	11.0	4.0	1.2	4.3	—	13.2
50	0.13	2.00	1.04	40.0	130	6.1	0.06	—	0.34	1980	0.8	10	44.0	4.0	27.1	4.1	0.015	0.2
51	0.25	1.50	—	—	—	14.0	0.06	—	0.64	4392	1.4	19	69.0	4.0	29.9	5.7	0.015	—
52	0.23	0.07	0.38	32.8	120	5.2	1.00	39	1.05	3984	9.9	448	109.0	42.8	37.0	91.8	—	—

TABLE 10 Average Amino Acid Composition of Some Commonly Used Feedstuffs[a]

	International Feed Number[b]	Protein (%)	Arginine (%)	Histidine (%)	Isoleucine (%)	Leucine (%)	Lysine (%)	Methionine (%)	Cystine (%)	Phenylalanine (%)	Tyrosine (%)	Threonine (%)	Tryptophan (%)	Valine (%)
Alfalfa meal, dehy., 17% protein	1-00-023	17.5	0.8	0.3	0.8	1.3	0.73	0.2	0.2	0.8	0.6	0.70	0.28	0.8
Barley	4-00-549	11.6	0.6	0.3	0.5	0.8	0.40	0.2	0.3	0.6	0.3	0.42	0.14	0.6
Barley, Pacific Coast	4-07-939	9.0	0.5	0.2	0.4	0.6	0.29	0.1	0.2	0.5	0.3	0.30	0.12	0.5
Beans, field (*Vicia faba*)	5-09-262	27.4	2.5	0.7	1.1	1.9	1.72	0.2	0.2	1.2	0.7	3.96	0.24	1.2
Beet pulp, dried	4-00-669	8.0	0.3	0.2	0.3	0.6	0.60	0.01	0.01	0.3	0.4	0.40	0.10	0.4
Blood meal, spray or ring dried	5-00-381	85.0	4.1	5.5	1.0	12.7	8.10	1.5	1.5	7.3	3.0	4.90	1.10	9.1
Brewers dried grains	5-02-141	25.3	0.8	0.6	1.4	2.5	0.90	0.6	0.4	1.5	1.2	0.98	0.34	1.7
Corn, dent yellow, grain	4-02-935	8.8	0.5	0.2	0.4	1.1	0.24	0.2	0.2	0.5	0.5	0.39	0.05	0.4
Corn and cob meal	4-02-849	7.8	0.4	0.2	0.4	1.0	0.18	0.1	0.1	0.4	—	0.35	0.07	0.4
Corn, gluten feed	5-02-903	22.0	1.0	0.7	0.7	1.9	0.63	0.5	0.5	0.8	0.6	0.89	0.10	1.0
gluten meal, 41%	5-02-411	40.6	1.4	1.0	2.2	7.2	0.78	1.0	0.7	2.9	1.0	1.40	0.21	2.2
Corn, distillers grain w/solubles, dehy.	5-02-843	27.2	1.0	0.7	1.0	2.6	0.60	0.6	0.3	1.2	0.7	0.92	0.19	1.3
Corn, distillers solubles, dehy.	5-02-844	28.5	1.1	0.7	1.3	2.1	0.90	0.5	0.4	1.3	1.0	1.00	0.30	1.4
Corn, hominy feed	4-02-887	10.0	0.5	0.2	0.4	0.8	0.40	0.1	0.1	0.4	0.5	0.40	0.10	0.5
Cottonseed meal, mechanical extracted	5-01-609	40.9	4.3	1.1	1.6	2.5	1.51	0.6	0.6	2.2	1.1	1.38	0.55	2.0
Cottonseed meal, solvent extracted	5-01-619	41.4	4.6	1.1	1.3	2.4	1.71	0.5	0.6	2.2	1.0	1.32	0.47	1.9
Feather meal	5-03-795	86.4	3.9	0.3	2.7	6.7	1.10	0.4	3.0	2.7	6.3	2.80	0.50	4.6
Fish meal, anchovy	5-01-985	64.2	3.7	1.5	3.0	5.0	5.10	1.9	0.6	2.7	2.2	2.68	0.74	3.4
herring	5-02-000	72.3	4.8	1.7	3.2	5.3	5.70	2.1	0.7	2.8	2.3	3.00	0.81	4.4
Menhaden	5-02-009	60.5	3.8	1.5	2.9	5.0	4.83	1.8	0.6	2.5	2.0	2.50	0.68	3.2
Fish solubles, 50% solids	5-01-969	31.5	1.6	1.6	0.7	1.9	1.73	0.5	0.3	0.9	0.4	0.86	0.31	1.2
Meat and bone meal, 50%	5-09-322	50.4	3.6	1.2	1.4	3.2	2.60	0.7	0.3	1.5	0.8	1.50	0.28	2.3
Meat meal, 55%	5-09-323	54.4	3.7	1.3	1.6	3.3	3.00	0.8	0.7	1.7	1.8	1.74	0.36	2.6
Oats	4-03-309	11.4	0.8	0.2	0.5	0.9	0.40	0.2	0.2	0.6	0.5	0.43	0.16	0.7
Oat groats (dehulled oats)	4-03-331	16.0	0.7	0.3	0.5	1.0	0.60	0.2	0.3	0.7	0.9	0.50	0.18	0.7
Peas	5-03-600	23.8	1.4	0.7	1.1	1.8	1.60	0.3	0.2	1.3	—	0.94	0.24	1.3
Peanut meal, expeller	5-03-649	45.0	4.7	1.1	1.8	3.6	1.55	0.4	0.7	2.6	—	1.40	0.46	2.6
Peanut meal, solvent	5-03-650	47.0	4.9	1.2	2.1	3.7	1.76	0.4	0.8	2.8	2.0	1.45	0.48	2.8
Rapeseed meal, solvent	5-03-871	35.0	1.9	1.0	1.3	2.3	2.10	0.7	0.4	1.4	0.8	1.53	0.45	1.8
Rice bran, solvent	4-03-930	12.9	0.9	0.3	0.4	0.9	0.59	0.2	0.1	0.6	0.7	0.48	0.15	0.6
Rice, broken	4-03-932	8.7	0.6	0.2	0.3	0.5	0.24	0.1	0.1	0.3	—	0.27	0.10	0.5
Rice, polishings	4-03-943	12.2	0.8	0.2	0.4	0.8	0.57	0.2	0.1	0.5	0.6	0.40	0.13	0.8
Rye, grain	4-04-047	12.6	0.5	0.3	0.5	0.7	0.49	0.2	0.2	0.6	0.3	0.86	0.12	0.6
Safflower meal, solvent	5-04-110	28.5	3.7	1.0	1.7	2.5	1.30	0.7	0.7	1.9	—	1.35	0.60	2.3
Sesame meal, expeller	5-04-220	42.0	4.2	1.1	2.1	3.3	1.30	1.2	0.6	2.2	2.0	1.65	0.80	2.4
Skim milk, dried	5-01-175	33.5	1.1	0.8	2.2	3.2	2.40	0.9	0.4	1.6	1.1	1.60	0.44	2.3
Sorghum, grain (Milo)	4-04-383	8.9	0.4	0.3	0.5	1.4	0.22	0.1	0.2	0.4	0.4	0.27	0.10	0.5
Soybeans, full-fat cooked	5-04-597	37.0	2.8	0.9	2.0	2.8	2.40	0.5	0.6	1.8	1.2	1.50	0.55	1.8
Soybean meal, dehulled, solvent	5-04-612	48.5	3.7	1.3	2.6	3.8	3.18	0.7	0.7	2.1	2.0	1.91	0.67	2.7
Soybean meal, solvent	5-04-604	44.0	3.3	1.2	2.4	3.5	2.93	0.7	0.7	2.3	1.3	1.81	0.62	2.3
Sunflower meal, dehulled, solvent	5-04-739	42.0	3.3	1.4	2.8	3.9	1.70	0.7	0.7	2.9	1.2	2.13	0.71	3.2
Wheat bran	4-05-190	15.7	1.0	0.3	0.6	0.9	0.59	0.2	0.3	0.5	0.4	0.42	0.30	0.7
Wheat, hard, red winter	4-05-268	14.1	0.6	0.2	0.6	0.9	0.40	0.2	0.3	0.7	0.6	0.37	0.18	0.6
Wheat middlings	4-05-205	16.0	1.8	0.4	0.6	1.1	0.69	0.2	0.3	0.6	0.5	0.49	0.20	0.7
Wheat shorts	4-05-201	16.8	1.2	0.5	0.6	1.1	0.81	0.2	0.3	0.7	0.5	0.61	0.19	0.8
Wheat, soft, red winter	4-05-294	10.2	0.4	0.2	0.4	0.6	0.31	0.2	0.2	0.5	0.4	0.32	0.12	0.4
Whey, dried	4-01-182	12.0	0.3	0.2	0.8	1.2	0.97	0.2	0.3	0.3	0.3	0.89	0.19	0.7
Whey, low lactose	4-01-186	15.5	0.7	0.1	0.3	0.2	1.47	0.6	0.6	0.1	0.2	0.50	0.18	0.3
Yeast, brewers dried	4-05-527	44.4	2.2	1.1	2.1	3.2	3.23	0.7	0.5	1.8	1.5	2.06	0.49	2.3

[a]As fed basis.
[b]The first digit is the feed class, coded as follows: (1) dry forages and roughages; (2) pasture, range plants and forages fed green; (3) silages; (4) energy feeds and (5) protein supplements.

TABLE 11 Common Mineral Sources For Swine

Mineral	Source	Chemical Formula	Mineral Content[a]			
Calcium	Calcium carbonate		40%Ca	0.02%Na		
	Limestone		38%Ca	0.05%Na	0.01%F	
Calcium and phosphorus	Bone meal		24%Ca	12.6 %P	0.37%Na	0.05%F
	Phosphate, curacao		36%Ca	14 %P	0.3 %Na	0.54%F
	defluorinated		30-34%Ca	18 %P	5.7 %Na	0.16%F
	dicalcium		18–24%Ca	18.5 %P	0.6 %Na	0.14%F
	mono and dicalcium		16–19%Ca	21 %P	0.6 %Na	0.20%F
	soft rock		17%Ca	9 %P	0.1 %Na	1.2 %F
	sodium tripoly		0	25 %P	31.2 %Na	0.03%F
Sodium and chlorine	Sodium chloride		39.3 %Na	60.7 %Cl		
Iron	Ferrous sulfate	$FeSO_4\ H_2O$	32.9 %Fe			
	Ferrous sulfate	$FeSO_4\ 7H_2O$	20.1 %Fe			
	Ferric ammonium citrate		16.5–18.5 %Fe			
	Ferrous fumarate	$FeC_4H_2O_4$	32.9 %Fe			
	Ferric chloride	$FeCl_3\ 6H_2O$	20.7 %Fe			
	Ferrous carbonate	$FeCO_3$	48.2 %Fe			
	Ferric oxide	Fe_2O_3	69.9 %Fe			
	Ferrous oxide	FeO	77.8 %Fe			
Copper	Cupric carbonate	$CuCO_3\ Cu(OH)_2$	57.5 %Cu			
	Cupric chloride	$CuCl_2\ 2H_2O$	37.3 %Cu			
	Cupric hydroxide	$Cu(OH)_2$	65.1 %Cu			
	Cupric oxide	CuO	79.9 %Cu			
	Cupric sulfate	$CuSO_4\ 5H_2O$	25.4 %Cu			
Manganese	Manganese carbonate	$MnCO_3$	47.8 %Mn			
	Manganous chloride	$MnCl_2\ 4H_2O$	27.8 %Mn			
	Manganous oxide	MnO	77.4 %Mn			
	Manganese sulfate	$MnSO_4\ 5H_2O$	22.7 %Mn			
	Manganous sulfate	$MnSO_4\ H_2O$	32.5 %Mn			
Zinc	Zinc carbonate	$5ZnO\ 2CO_2\ 4H_2O$	56.0 %Zn			
	Zinc chloride	$ZnCl_2$	48.0 %Zn			
	Zinc oxide	ZnO	80.3 %Zn			
	Zinc sulfate	$ZnSO_4\ 7H_2O$	22.7 %Zn			
	Zinc sulfate	$ZnSO_4\ H_2O$	36.4 %Zn			
Iodine	Calcium iodate	$Ca(IO_3)_2$	65.1 %I			
	Potassium iodide	KI	76.4 %I			
	Cuprous iodide	CuI	66.6 %I			
	Penta calcium orthoperiodate	$Ca_5(IO_6)_2$	39.3 %I			
Selenium	Sodium selenite	Na_2SeO_3	45.6 %Se	26.6 %Na		
	Sodium selenate	Na_2SeO_4	41.8 %Se	24.3 %Na		

[a] Actual mineral levels in technical grade sources may vary.

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DATE LOANED	BORROWER S NAME	DATE RETURNED