Minerals for Swine – Pork Industry Handbook
Michigan State University Extension Service
Gary L. Cromwell, University of Kentucky; Donald C. Mahan, The Ohio State University; William C. Weldon, Bonner Springs, Kansas
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Minerals For Swine

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Authors:
Gary L. Cromwell, University of Kentucky
Donald C. Mahan, The Ohio State University
William C. Weldon, Bonner Springs, Kansas

Reviewers:
Dale Forsyth, Purdue University
Gretchen Myers Hill, Michigan State University

Minerals serve a variety of structural and metabolic functions in swine. Minerals are found in all body components, including bone, muscle, internal organs, blood, and other tissues and fluids of the body. Some minerals are found in relatively large amounts while others are found in minute quantities.

Those minerals known to be required in the diet include calcium, phosphorus, sodium, chlorine, potassium, magnesium, sulfur, iron, zinc, copper, manganese, iodine, and selenium. Cobalt is a component of Vitamin B_{12}, but there is not a specific dietary need for cobalt. Recent evidence suggests chromium may be a dietary essential trace mineral. Other minerals that play a physiological role in laboratory animals include arsenic, boron, bromine, fluorine, molybdenum, silicon, nickel, tin, and vanadium. Some or all of these minerals also may be required by pigs, but they are needed at such low dietary concentrations that their dietary essentiality has not been demonstrated.

Minerals Needed

Ten mineral elements are regularly added to swine diets because the natural ingredients commonly used in swine diets (cereal grain, soybean meal, etc.) are deficient. These minerals can be divided into two groups, macro- and microminerals, based on the amounts normally added. The requirements for, and dietary concentrations of, the macrominerals are generally expressed on a percentage basis, whereas the microminerals are expressed on a part per million (ppm) or milligram (mg) per pound basis.

Macrominerals Added	Microminerals Added
Calcium	Iron
Phosphorus	Zinc
Sodium	Copper
Chlorine	Manganese
	Iodine
	Selenium

Recommended dietary concentrations of macro- and microminerals for pigs from birth to market are presented in Table 1 and for breeding animals in Table 2. The recommendations for growing pigs are based on the assumption that pigs have *ad libitum* access to feed. Recommendations for sows are based on a daily feed intake of not less than four pounds during gestation and not less than 10 pounds during lactation. These mineral levels also should be satisfactory for mature boars that are fed at least 4 pounds of feed daily. If feed intake differs, adjustment of mineral concentration may be necessary. Excess levels should be avoided because they increase costs and create dietary or metabolic imbalances that may impair pig performance.

Calcium and phosphorus. About 99% of the calcium and 80% of the phosphorus in the body is located in the skeleton and teeth. The remainder of the calcium and phosphorus is in the soft tissues and fluids of the body where they perform vital functions. Calcium plays a role in blood clotting and muscle contraction, while phosphorus is involved with energy and protein metabolism.

Most grains and plant protein sources are very low in calcium and moderate in phosphorus. Also, more than half of the phosphorus in grains, plant protein sources and their by products occur as phytic acid (or phytate), an

Table 1. Suggested mineral concentrations in complete diets for weanling, growing, and finishing pigs.

	Body Weight (lb)					
Mineral	8-15	15-20	20-45	45-75	75-140	140-market
Calcium, %	1.00	.90	.80	.70	.65	.60
Phosphorus, %	.90	.80	.70	.60	.55	.50
Available phosphorus, %	.70	.60	.45	.35	.30	.25
Sodium chloride (salt), %	.40-.50	.35-.50	.35-.50	.25-.50	.25-.50	.25-.50
Iron, ppm	100	100	100	100	100	100
Zinc, ppm	100	100	100	100	100	100
Copper, ppm	10	10	10	10	10	10
Manganese, ppm	10	10	10	10	10	10
Iodine, ppm	.2	.2	.2	.2	.2	.2
Selenium, ppm	.3	.3	.3	.3	.3	.3

Table 2. Suggested mineral concentrations in complete diets for breeding swine.

Mineral	Gestating and Lactating Gilts and Sows[a] Young and Adult Boars
Calcium, %	.90
Phosphorus, %	.70
Available phosphorus, %	.45
Sodium chloride (salt), %	.40-.50
Iron, ppm	100
Zinc, ppm	100
Copper, ppm	10
Manganese, ppm	20
Iodine, ppm	.2
Selenium, ppm	.3

[a]Based on a minimum of 4 pounds/day during gestation and 10 pounds/day during lactation.

organically-bound form of phosphorus that is poorly available to pigs. Phosphorus bioavailability in grains and oilseed meals varies from near 0 to 50% as compared to the bioavailability of phosphorus in inorganic phosphate supplements such as dicalcium phosphate. The phosphorus in wheat and high-moisture grain has a higher bioavailability (~50%) than the phosphorus in corn or grain sorghum (~10% to 15%). Meat and bone meal, fish meal, and dried milk products contain liberal quantities of highly available calcium and phosphorus.

Symptoms of calcium or phosphorus deficiency include impaired bone mineralization often evidenced as bowed or broken bones, fractured ribs, and fractured or crushed vertebrae. These symptoms are most prevalent in young, rapidly growing pigs and in sows toward the end of lactation. Reduction in growth rate also occurs when phosphorus is deficient, but generally does not occur when calcium is deficient.

The optimal ratio of total calcium to total phosphorus is from 1:1 to 1.25:1. Higher calcium:phosphorus ratios are tolerable provided the diet contains ample phosphorus. When phosphorus is marginal, a wide calcium:phosphorus ratio can result in a phosphorus deficiency. Excessive calcium, especially in high phytate diets, also binds zinc in the intestinal tract, and can result in a zinc deficiency.

Phytase is an enzyme recently cleared for addition to pig diets. This enzyme degrades some of the phytic acid in cereal grains and oilseed meals resulting in more of the phosphorus being available for absorption. When phytase is included in diets, the amount of supplemental inorganic phosphorus can be reduced. Degradation of phytic acid also increases the bioavailability of calcium, zinc, and other trace minerals. A major advantage of this enzyme is that less phosphorus is excreted into the environment.

Sodium and chlorine. These two elements assist in maintaining the osmotic pressure of body fluids. Sodium also is involved in nerve function, and chlorine is essential for hydrochloric acid production in the stomach. A deficiency of sodium and chlorine depresses appetite and impairs growth. Grains and plant protein supplements are low in sodium and chloride, so these minerals must be added to the diet. They are generally added as common salt, which is 40% sodium and 60% chloride. The needs of growing-finishing pigs can be met by including .25% salt (sodium chloride) in the diet. The needs of young pigs are met by adding 0.35% to 0.40% salt. If diets contain high levels of dried milk products and/or dried plasma protein, both of which are high in sodium and chlorine, some adjustment in the salt level should be considered. The needs of pregnant sows, lactating sows, and boars are met by adding 0.50% salt to the diet.

High levels of salt can be tolerated if adequate drinking water is available. If water is restricted, as little as 2.0% dietary salt can produce toxicity (salt poisoning), characterized by nervousness, weakness, staggering, epileptic seizures, and death.

Potassium, magnesium, and sulfur. Potassium is the most abundant mineral in muscle tissue . It is involved in electrolyte balance and nerve function. Magnesium is a cofactor in many enzyme systems. These two minerals, along with sulfur, are generally not supplemented because cereal grains and other feedstuffs contain ample amounts for the pig's requirements.

Iron. Iron is required for the synthesis of hemoglobin (the protein that transports oxygen in red blood cells), myoglobin, and a number of iron-containing enzymes found in the body. The baby pig is born with a limited supply of iron to meet its needs, and sow's milk is low in iron. Because the baby pig's diet consists solely of milk, iron-deficiency anemia can be a common problem in young pigs. An intramuscular injection of 100 mg to 200 mg of iron from iron dextran, iron dextrin, or gleptoferron is commonly given between one to three days of age to prevent anemia. Feeding extra iron to the sow will not raise the iron content in the milk, but it will increase the iron content of her feces. Ingestion of small quantities of iron-rich fecal material by nursing pigs helps to meet their iron requirement.

Corn and grain sorghum are low in iron, but inorganic phosphate supplements such as mono- or dicalcium phosphate and defluorinated rock phosphate are relatively high in iron. High dietary levels of copper or zinc, commonly included in starter diets, may increase the pig's need for supplemental iron; thus, iron supplementation is recommended. Ferrous sulfate is an effective dietary iron supplement with high bioavailability. Ferric oxide is a poor source because the iron is not biologically available. The iron availability in ferrous carbonate varies with sources, but is generally considered to be lower in iron availability than ferrous sulfate.

Signs of iron deficiency include pale mucous membranes, chalky skin color in white-skinned pigs, enlarged heart, spasmodic breathing after exercise (thumps), low hemoglobin, and decreased resistance to certain bacterial infections. Excess iron can be toxic, producing incoordination, nervousness, and convulsions.

Zinc. Zinc is important to the proper function of several enzymes and is essential for normal epidermal tissue development. Zinc deficiency results in a rough, scaly skin condition called parakeratosis, loss of appetite, poor growth, and impaired sexual development. The concentration of this element is low in grains and plant proteins, but is higher in animal products such as meat and bone meal. Much of the zinc in cereal grains and oilseed meals is associated with phytic acid which binds this mineral and makes it poorly available. Forms of supplemental inorganic zinc include zinc oxide, zinc sulfate, and zinc carbonate.

High levels of zinc (3,000 ppm zinc as zinc oxide) have recently been shown to stimulate growth rate in early weaned pigs, and in some instances to reduce the incidence of diarrhea. Other forms of zinc are not effective for these purposes. The mechanism of how zinc performs this function is unknown.

Zinc toxicity can result from the feeding of 2,000 ppm zinc from zinc sulfate or zinc carbonate for an extended period of time. Symptoms include growth depression, inflammation of the gastrointestinal tract, arthritis, and hemorrhage. Zinc toxicity does not result from the feeding of 3,000 ppm zinc from zinc oxide, apparently because of the reduced bioavailability of the zinc in the oxide form versus the carbonate or sulfate forms.

Iodine. Iodine is a vital component of the thyroid hormones and, therefore, it affects the pig's metabolic rate. Weakness, hairlessness, thick pulpy skin, goiter, and death have been observed in pigs born to iodine-deficient sows. Much of the glaciated and sandy areas of the United States are iodine deficient because this element has been leached from the soil. Consequently, feeds grown on these soils are deficient in iodine. In addition, certain feedstuffs contain goitrogens that increase the iodine requirement. Meat and bone meal iodine content is variable and should not be relied upon as a source of iodine; however, fish meal generally is a good iodine source. Iodine is often added to the diet as iodized salt.

Selenium. Selenium is a component of an enzyme that protects cell contents and membranes against oxidative damage. It is also a component of other body selenoproteins (e.g., enzymes, spermatozoa) and thus is critical at all production phases. Many soils (especially acidic soils) in the United States are deficient in this element. As a consequence, selenium concentration in feedstuffs produced in many regions may be deficient for swine.

The need for supplemental selenium is indirectly related to vitamin E intake, but there is a dietary requirement for both nutrients. With decreased access to soil (a source of selenium), pastures, and forages in swine diets (good sources of vitamin E), and the artificial drying of high-moisture grains (which destroys some of the vitamin E), supplemental selenium has become an important dietary supplement. The amount of selenium that may be added to swine diets is regulated by the Food and Drug

Table 3. Sources of calcium (Ca) and phosphorus (P) for swine.

Source	Mineral (%) Ca	P	Remarks
Ground limestone	38	0	High availability of Ca (equal to that of calcium carbonate). Less expensive source of Ca than the Ca in inorganic phosphate sources. Some sources may contain lower levels of Ca.
Dolomitic limestone	22	0	Availability of Ca is 50% to 75% of that of calcium carbonate.
Dicalcium phosphate[a]	22	18.5	High availability of Ca and P. Levels of Ca may vary.
Monocalcium phosphate[a]	16	21	High availability of Ca and P. Levels of Ca may vary.
Defluorinated phosphate	32	18	Availability of P is 85% to 90% of that of dicalcium phosphate.
Steamed bone meal	24	12	Moderate to high availability of P (80% to 85% of that of dicalcium phosphate).
Meat and bone meal	6-10	4-5	Moderate to high availability of P (70% to 90% of that of dicalcium phosphate).
Fish meal	5	3	High availability of P (equal to that of dicalcium phosphate).

[a]Commercial products consist of a blend of monocalcium and dicalcium phosphate.

Administration (FDA), and it is limited to 0.3 ppm of the diet. Sodium selenite or sodium selenate are currently the only approved sources of supplemental selenium in the United States.

Signs of selenium deficiency include sudden death (particularly in weaned pigs), an unusually pale muscle and dystrophy of muscle (white muscle disease), liver necrosis, mulberry heart, impaired reproduction, and edema of the mesentery of the spiral colon, lungs, pericardial sac, and gastrointestinal tissues.

Selenium toxicity has been produced by 5 ppm to 8 ppm of selenium in the diet (20 to 30 times the required level). Toxicity is characterized by reduced feed intake, depressed growth, loss of hair, stiffness and pain upon movement, separation of the hooves at the coronary band, erosion of the joints, atrophy of the heart, cirrhosis of the liver, anemia, and impaired embryo development.

Copper. Copper is required for the function of several enzymes. Also, it enhances iron absorption from the intestinal tract and iron mobilization from stores in the liver. Most feed ingredients probably supply sufficient copper; however, since information on copper requirements is limited, some supplemental copper (1:10 ratio with iron) is recommended. The most common signs of copper deficiency include reduced growth, nervous disorders, incoordination, defective bone formation, and small, hemoglobin-deficient red blood cells.

Levels of copper that are considerably higher than the nutritional requirement (i.e., 100 ppm to 250 ppm of copper) will stimulate growth and feed intake in pigs. This response is considered an antibiotic-like or pharmacological effect. The stage at which high dietary copper is most effective in stimulating growth is in weanling pigs, and the response is in addition to that achieved by feeding antibiotics.

Copper sulfate is the most common source of highly available copper. Other good sources include copper chloride, copper carbonate, and chelated or complexed copper (copper-lysine, copper-methionine). The copper in copper oxide and copper sulfide is unavailable to pigs.

Copper toxicity has been produced by feeding high levels (greater than 250 ppm) of copper throughout the growing-finishing period when the diet contains low levels of zinc and iron. Extra zinc and iron helps to prevent the effects of excess copper. Signs of toxicity include impaired growth, anemia, jaundice, and eventual death.

Manganese. Manganese is necessary for the proper function of a number of enzymes, some of which influence energy metabolism, bone development, and reproduction. Signs of manganese deficiency include impaired growth, lameness, enlarged hocks, crooked and shortened legs, irregular estrus, poor mammary development and lactational performance, and the birth of small, weak pigs with an impaired sense of balance. Minimum requirements have not been defined, and there is not a consensus on the amount needed by pigs.

Chromium. Chromium is involved with carbohydrate, fat, and protein metabolism. This mineral acts as a cofactor with insulin to regulate blood glucose levels in pigs. A dietary requirement for chromium has not been established for the pig, but supplemental levels of chromium, as chromium picolinate, have resulted in increased carcass leanness and improved reproductive performance in some studies.

Cobalt. This mineral is thought to function only as a component of Vitamin B_{12}. Unlike ruminants, pigs are unable to synthesize Vitamin B_{12} efficiently, so there is no dietary requirement for cobalt if Vitamin B_{12} is supplemented.

Mineral Supplements

Calcium and phosphorus sources. The ingredients normally used in formulating swine diets vary widely in their mineral content. The cereal grains are almost devoid of calcium and, while they contain some phosphorus, it is poorly utilized by swine. Grain-soybean meal diets, therefore, must be supplemented with both calcium and inorganic phosphorus. Specific suggestions are given in PIH-23, "Swine Diets." Feeds of animal origin such as dried milk products, meat and bone meal, or fish meal are quite high in calcium and available phosphorus. The standard sources used to supplement calcium and phosphorus in swine diets are ground limestone and either dicalcium phosphate or defluorinated phosphate.

Although dicalcium phosphate is the most commonly used phosphorus source, other sources that can be used to replace this phosphorus source in swine diets are shown in Table 3. Most of these sources supply both calcium and phosphorus, thus the quantity of ground limestone used in the diet will vary depending upon the phosphorus source used. It is extremely important to check the feed tag on the mineral sources because the levels of calcium and phosphorus may vary from tabular values.

Dietary levels of calcium and phosphorus that will achieve maximum body weight gain are less than the levels that will achieve maximum bone development. A borderline deficiency of calcium or phosphorus may go unnoticed in growing-finishing pigs yet produce serious damage in pigs saved for breeding purposes. Breeding animals should be fed higher dietary levels of calcium and phosphorus to meet their needs for reproduction and milk production.

The recommended calcium and phosphorus levels (Table 1) for growing-finishing pigs may not be adequate for developing replacement gilts and boars. Limit feeding replacement gilts a finishing diet will result in intakes of calcium and phosphorus that will not support adequate bone mineralization. Feeding the gestation or lactation diet to replacement gilts and boars will better ensure that the developing animals receive adequate calcium and phosphorus.

Sodium and chlorine source. The need for these two elements can be met by adding 5 to 10 pounds of salt (sodium chloride) per ton of diet for all stages. Many producers routinely add 10 pounds of salt per ton, but this may be in excess of need, particularly for growing-finishing swine. Although these levels will exceed the pig's requirements for sodium and chloride, there is no danger of salt toxicity if adequate fresh water is provided.

Micromineral premixes. Usually, the need for supplemental iron, zinc, iodine, copper, manganese, and selenium is met by adding a commercial vitamin-mineral base mix, trace mineralized salt (specifically formulated for swine), or a trace mineral premix. In some instances, selenium is not included in the trace mineral premix and is added separately as a selenium supplement. This allows variable amounts of the trace mineral premix to be included in the diet depending on the stage of production, while selenium is often added at a constant level to supply the maximum amount allowable by the FDA (0.3 ppm). An example trace mineral premix and recommended fortification levels for various weight and production classes are given in PIH-23.

Trace mineral mixtures vary greatly in the number of minerals included and in their concentrations. The actual levels of minerals in the trace mineral mix should be checked against the animal's requirements at each stage of growth. Table 4 provides a method to evaluate a particular source of trace minerals.

Table 4. Trace mineral check sheet[a].

	Concentration in premix (%)	X	Pounds of premix per ton	X 5 =	ppm	Recommended levels (ppm)	Toxic level (ppm)
Copper	____		____		____	10	300[b]
Iron	____		____		____	100	5,000
Iodine	____		____		____	.2	____
Selenium	____		____		____	.3	15
Manganese	____		____		____	10	4,000
Zinc	____		____		____	100	2,000[c]

[a]For example, if premix contains 4% copper and 3 pounds of premix are included in a ton of feed, the concentration of copper in the diet is 60 ppm (4 x 3 x 5 = 60).
[b]In absence of adequate levels of iron and zinc.
[c]Higher levels of zinc (3,000 ppm) from zinc oxide can be fed to weanling pigs for 1 to 4 weeks without toxic effects.

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