Vitamin Sources for Swine Diets

Vitamins are required for normal metabolism in physiological functions such as growth, development, maintenance, and reproduction. Some vitamins are produced by the pig in sufficient quantities to meet its needs while others are present in adequate amounts in feed ingredients commonly used in swine diets. However, several vitamins need to be added to swine diets in the form of a vitamin premix to avoid deficiency and obtain optimal performance. The sources of vitamins used in swine diets are discussed in this fact sheet.

Fat-soluble vitamins

Vitamins A, D, E, and K are fat-soluble vitamins and are mainly involved in tissue development, calcium and phosphorus metabolism, antioxidant defense, and blood clotting, respectively.

Vitamin A

Vitamin A is essential for vision, reproduction, and tissue development. Grains and oilseeds commonly used in swine diets have a precursor of vitamin A, β-carotene, which is converted in vitamin A in the intestine of the pig. However, β-carotene is found in low concentration and is easily degraded. Vitamin A deficiency is characterized by blindness, incoordination, reproductive failures, and low growth rate. Vitamin A toxicity develops above 20,000 IU/kg for growing pigs and 40,000 IU/kg for sows, and signs include scaly skin, rough hair coat, and incoordination (NRC, 2012).

Vitamin D

Vitamin D is essential for calcium and phosphorus absorption and thus, is important for bone mineralization. Grains and oilseeds commonly used in swine diets have a form of vitamin D which requires exposure of pigs to sunlight to become active. In enclosed swine facilities, the active form of vitamin D, vitamin D_3, needs to be supplemented in the diet. Vitamin D deficiency is characterized by rickets in growing pigs and osteoporosis in sows, which are manifested as lameness and fractures. Vitamin D toxicity develops above 2,200 IU D_3/kg for long-term feeding or 33,000 IU D_3/kg for short-term feeding, and causes mineralization of soft tissues (NRC, 2012).

Vitamin E

Vitamin E is important for antioxidant defense. Vitamin E and selenium have closely related functions, but requirements are independent of one another. Vitamin E content in grains and oilseeds commonly used in swine diets is mostly lost during storage and processing. Vitamin E deficiency signs are similar to signs of selenium deficiency, which includes white muscle disease, mulberry heart disease, sudden death, and impaired reproduction.

Vitamin K

Vitamin K is essential for blood clotting. Vitamin K is available in feedstuffs of plant origin (K_1), produced by the intestinal microbiota of pigs (K_2), and added to the diet in synthetic form (K_3). Vitamin K deficiency is characterized by prolonged blood clotting time and hemorrhages.

Water-soluble vitamins

The B-complex vitamins are water-soluble vitamins and are required as co-enzymes in several metabolic processes. The B vitamins added in swine diets are riboflavin, niacin, pantothenic acid, and vitamin B_{12}. In addition, folic acid, pyridoxine, choline, and biotin are included in sow diets due to the influence of these vitamins on reproductive performance.

Pantothenic acid

Pantothenic acid is an important component of enzymes involved in the metabolism of protein, carbohydrate, and fat. Pantothenic acid content is variable in grains and oilseeds commonly used in swine diets. Pantothenic acid deficiency causes non-specific signs, such as low growth rate, low intake, rough hair coat, diarrhea, and reproductive failure. A characteristic sign of pantothenic acid deficiency is a gait disorder in the rear legs, which includes tremor, stiffness, and a high-stepping gait called 'goose stepping'.

Riboflavin

Riboflavin is an essential component of enzymes involved in the metabolism of protein, carbohydrate, and fat. Riboflavin content is typically low in grains and oilseeds commonly used in swine diets. Riboflavin deficiency causes non-specific signs, such as low growth rate, low intake, skin lesions, rough hair coat, diarrhea, and reproductive failure.

Niacin

Niacin is an important component of enzymes involved in many metabolic reactions. Grains commonly used in swine diets contain adequate amounts of niacin, but in a bound form unavailable to pigs. Niacin deficiency is characterized by skin lesions, rough hair coat, hair loss, diarrhea, vomiting, and lesions in the digestive tract.

Vitamin B_{12}

Vitamin B_{12} is an essential component of enzymes involved in several metabolic functions. Feedstuffs of plant origin do not contain vitamin B_{12}, whereas proteins of animal origin are good sources of vitamin B_{12}. Vitamin B_{12} deficiency causes non-specific signs, such as low growth rate, low intake, rough hair coat, incoordination, and reproductive failure. A typical sign of vitamin B_{12} deficiency is anemia.

Folic acid

Folic acid is mainly added to sow diets. Folic acid is involved in the synthesis of essential components for cell development and function. Grains and oilseeds commonly used in swine diets have adequate concentration of folic acid to meet the requirement of growing pigs. Folic acid supplementation in sows is particularly important for adequate development of conceptus and to improve litter size and live born piglets.

Pyridoxine

Pyridoxin is mainly added to sow diets. Pyridoxine is an essential component of enzymes involved in amino acid metabolism. Grains and oilseeds commonly used in swine diets have adequate concentration of pyridoxine to meet the requirement of growing pigs. Pyridoxine supplementation in sows is found to improve litter size and wean-to-estrus interval.

Choline

Choline is mainly added to sow diets. Choline is involved in many essential metabolic functions for cell structure, nervous function, and amino acid metabolism. Choline is present in adequate amounts in grains and oilseeds commonly used in swine diets and pigs are also able to produce choline to meet the requirements. Choline supplementation in sows is found to improve conception rate, farrowing rate, litter size, live born piglets, and weaned piglets.

Biotin

Biotin is mainly added to sow diets. Biotin is an essential component of enzymes involved in the metabolism of protein, carbohydrate, and fat. Grains and oilseeds commonly used in swine diets have adequate concentration of biotin to meet the requirement of growing pigs. Biotin supplementation in sows is found to improve litter size, live born piglets, and weaned piglets, and to enhance hoof soundness.

KSU Vitamin premix

A suggested vitamin premix is available at KSU Premix & Diet Recommendations. This single premix can be used in diets for all stages of production by adjusting the inclusion rate for sow, nursery, grower, and finisher diets. A sow add pack is also available for sow diets to supply the specific vitamins to enhance reproduction.

Vitamins can be combined with trace minerals in a VTM premix, but it is recommended to have separate premixes because trace minerals can affect the vitamin stability. Otherwise, VTM premix age must be monitored to ensure it is used before excess vitamin loss.

Vitamin sources

Synthetic vitamins are widely used in premixes for swine diets. The commercially synthesized vitamins are modified from natural vitamin forms to improve their stability, compatibility, mixability, and handling characteristics for feed supplementation. The natural source of vitamin E, d-α-tocopheryl acetate or natural vitamin E, is the only non-synthetic vitamin often used in swine diets. A list of sources of vitamins and respective units of activity is presented in **Table 1**.

The form of vitamin products determines important characteristics of vitamin quality. Vitamin forms with good stability are usually able to maintain good vitamin bioavailability. Vitamin forms with high flowability, high uniformity in mix, low dusting, and low caking provide optimal handling and mixing characteristics. Altogether, these characteristics are important because vitamins are added in such small amounts to swine diets that the presence or absence of vitamins in individual rations markedly affect performance and health.

Vitamin levels

The vitamin content of feed ingredients is usually disregarded in diet formulation because of imprecision and variation on methods of analysis, characteristics of ingredients, and degradation of vitamins in storage and processing (Gaudré and Quiniou, 2009). Thus, vitamin levels in the vitamin premix are calculated to fully supply the vitamin requirements of swine. Also, it appears to be standard practice to add a margin of safety for vitamin levels beyond the NRC (2012) requirement estimates (Flohr et al., 2016). The margin of safety intends to account for fluctuations in daily feed consumption and degradation of vitamins in storage and processing.

Vitamin stability

The stability of vitamins in a premix is critical in maintaining vitamin potency. Susceptibility to degradation varies depending on individual vitamins and on a number of factors that affect vitamin stability. Safety margins for vitamin premix formulation are usually based upon vitamin cost, presence or absence of trace minerals and choline in the premix, feed processing characteristics, environmental conditions, anticipated storage time, and expected rates of vitamin potency losses (Shurson et al., 2011).

Factors affecting vitamin stability

Vitamin stability in premixes is affected by exposure to light, heat, moisture, oxygen, and pH, and contact with other compounds. These factors subject vitamins to degradation primarily through oxidation. The long-term or multiple exposure to these factors generally magnifies the negative impact on vitamin stability. The individual vitamins vary in their susceptibility to degradation (**Table 2**). In general, the most sensitive or labile vitamins are vitamin K_3, vitamin A, pyridoxine, vitamin B_{12}, and folic acid (Shurson et al., 2011).

Vitamin stability in premixes

Premix composition affects vitamin stability, especially with regard to the presence or absence of choline and inorganic trace minerals. To maintain vitamin potency it is recommended to have vitamin premixes separated from choline and trace mineral premixes.

Choline is very hygroscopic and absorbs significant amounts of moisture from the environment, which affects the stability of other vitamins when added in the premix. Inorganic trace minerals also affect the stability of vitamins when added in the premix, as trace minerals often produce reduction and oxidation reactions in the premix. Among the inorganic trace mineral sources, the sulfates have greater effect on vitamin stability than carbonates and oxides. Use of organic trace mineral sources reduces vitamin activity losses by 40 to 50% during storage compared to adding inorganic trace minerals in a vitamin-trace mineral premix (Shurson et al., 2011).

Vitamin stability during feed processing

Some processes used in feed manufacturing affect vitamin stability (Reddy and Love, 1999). In swine diets, pelleting is typically the most aggressive process against vitamins due to exposure to heat, moisture, pressure, and abrasion. Mixing also affects vitamin stability due to abrasion and contact with other compounds in the diet.

Vitamin stability during storage

Vitamins are rather stable prior to preparation of a premix and remain reasonably stable in complete feeds. Consequently, most vitamin losses occur while the vitamin premix is under storage. Both storage time and storage conditions should be controlled for vitamin premixes. Vitamin premixes should be stored in a dry, cool, and dark place to maintain stability during storage. Also, the use of barriers such as plastic-lined bags aid in reducing the absorption of moisture.

Premixes containing vitamins exclusively can be stored for about 3 to 4 months. However, storage time should not exceed 60 days if choline and trace minerals are present in combination with vitamins in the premix.

During storage, vitamin potency can be monitored in premixes through a vitamin activity assay. Vitamin assay costs are generally expensive, which prompts the selection of one indicator vitamin to estimate the vitamin potency losses in the premix. According to Shurson et al. (2011), retinol appears to be the best indicator in the vitamin premix because of the low cost of assay, relatively high sensitivity of vitamin A to multiple factors, and high expected loss of activity per month of storage.

Technologies to improve vitamin stability

Advances in research and technology have led to the development of specialized vitamin forms to provide superior vitamin stability. Many commercial vitamin manufacturers have succeeded in enhancing stability of vitamins with spray-drying and beadlet technologies (DSM Vitamin Nutrition Compendium).

Spray-dried vitamin products are manufactured as a fine powder with high stability and good uniformity of mix, but only fair quality in terms of flowability, dustiness, and caking. Beadlets are produced by coating vitamins in gelatin or starch to prevent contact with factors affecting vitamin stability until it is digested by the pig. Beadlets are manufactured as a fine granular product with high stability and also high flowability, low dustiness, and low caking characteristics. Cross-linked beadlets are produced by coating vitamins with cross-linked gelatin proteins, which makes harder beadlets that are more resistant to the pressure and abrasion of pelleting. The inclusion of antioxidants in the beadlets provide additional protection against oxidative factors.

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Table 1. Sources of vitamins and respective units of activity				
Vitamin	Abbreviation	Principal compound	Source	Units of activity
Vitamin A	A	Retinol	Retinyl acetate	1 IU = 0.34 µg retinyl acetate
			Retinyl A palmitate	1 IU = 0.55 µg retinyl palmitate
			Retinyl A propionate	1 IU = 0.36 µg retinyl propionate
Vitamin D	D	Cholecalciferol (D_3)	Cholecalciferol (vitamin D_3)	1 IU = 0.025 µg cholecalciferol
Vitamin E	E	α-tocopherol	dl-α-tocopheryl acetate	1 mg = 1.0 IU dl-α-tocopheryl acetate
			d-α-tocopheryl acetate (natural vitamin E)	1 mg = 2.1 IU d-α-tocopheryl acetate[1]
			dl-α-tocopherol	1 mg = 1.11 IU dl-α-tocopherol
			d-α-tocopherol	1 mg = 1.49 IU d-α-tocopherol
Vitamin K	K	Menadione (K_3)	Menadione nicotinamide bisulfite (MNB)	1 Ansbacher unit = 20 Dam units = 0.0008 mg menadione
			Menadione dimethylpyrimidinol bisulfite (MPB)	
			Menadione sodium bisulfite complex (MSBC)	
Riboflavin	B_2	Riboflavin	Crystalline riboflavin	Commonly expressed as mg
Niacin	B_3	Niacinamide and nicotinic acid	Niacinamide	Commonly expressed as mg
			Nicotinic acid	Commonly expressed as mg
Pantothenic acid	B_5	Pantothenic acid	d-calcium pantothenate	1 mg = 0.92 mg d-pantothenic acid
			dl-calcium pantothenate	1 mg = 0.45 mg d-pantothenic acid
Vitamin B_{12}	B_{12}	Cobalamin	Cyanocobalamin	1 µg = 1 USP unit = 11,000 LLD units
Pyridoxine	B_6	Pyridoxine	Pyridoxine hydrochloride	1 mg = 0.823 mg pyridoxine
Choline	B_4	Choline	Choline chloride	1 mg = 0.868 mg choline
Biotin	H	Biotin	d-biotin	1 mg = 1 mg of activity
Folic acid	B_c	Pteroyglutamic acid and polyglutamate derivatives	Folic acid	1 mg = 1 mg of activity

Adapted from Reese and Hill (2010) and [1]Shelton et al. (2014). The vitamin sources listed in italic are less commonly used sources.

Table 2. Susceptibility of vitamins to factors affecting stability							
Vitamin	Abbreviation	Temperature	Humidity	Light	Oxygen	Acid pH	Alkaline pH
Vitamin A	A	Very sensitive	Sensitive	Very sensitive	Very sensitive	Sensitive	Stable
Vitamin D	D	Sensitive	Sensitive	Sensitive	Very sensitive	Sensitive	Stable
Vitamin E	E	Stable	Stable	Sensitive	Sensitive	Sensitive	Sensitive
Vitamin K	K	Sensitive	Very sensitive	Stable	Sensitive	Very sensitive	Stable
Riboflavin	B_2	Stable	Sensitive	Sensitive	Stable	Stable	Stable
Niacin	B_3	Stable	Stable	Stable	Stable	Stable	Stable
Pantothenic acid	B_5	Sensitive	Sensitive	Stable	Stable	Stable	Stable
Vitamin B_{12}	B_{12}	Very sensitive	Sensitive	Sensitive	Sensitive	Stable	Stable
Pyridoxine	B_6	Very sensitive	Sensitive	Sensitive	Stable	Sensitive	Stable
Biotin	H	Sensitive	Stable	Stable	Stable	Stable	Stable
Folic acid	B_c	Very sensitive	Sensitive	Very sensitive	Stable	Very sensitive	Stable

Adapted from DSM Vitamin Nutrition Compendium and Shurson et al. (2011).