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Swine nutrition and health connections

Jerry Shurson[1], PhD and Lee Johnston[2], PhD

University of Minnesota, [1]Department of Animal Science and [2]West Central Experiment Station

Introduction

Nutritionists and veterinarians have long recognized that providing adequate consumption of all essential nutrients is central to maintaining good health of pigs. Animals that are fed properly are more resistant to many bacterial and parasitic infections, which may be partially due to better body tissue integrity, more antibody production, more immunity to diseases, greater detoxifying ability, increased blood regeneration and other factors. In contrast, there are some indications that well-fed animals may be more susceptible to viral infections because these viruses need a well-nourished body cell in which to grow and reproduce (Cunha, 1984). Even though this may occur, we know that proper nutrition is essential for rapid recovery from all diseases, including those caused by viruses (Cunha, 1984).

As intensified pork production systems continue to increase in size and number, and as production rates increase, there is an increased need for better nutrition and health management. Optimal herd health requires that all parts of a production program fit together in a complementary system. Herd health programs can be fully effective only if pigs have adequate nutrition. Similarly, nutrient utilization efficiency can only be optimized if pigs have high health status. We know that high productivity increases nutrient requirements. We also know that high health status increases productivity and efficiency, but also increases nutrient requirements.

The purpose of this paper is to provide a comprehensive review of the connections and relationships between swine nutrition and health. Specifically, we have summarized our current understanding of how health/immune status affects nutrient partitioning and nutrient requirements. We have also reviewed and summarized a fairly well established body of knowledge involving the effects of nutrient deficiencies and toxicities on swine health. Finally, we have summarized the known toxins and antinutritional factors of common feedstuffs fed to swine, as well as some of the recently discovered immunological benefits from feeding some new animal protein sources.

Metabolic influence of the immune system on nutrient requirements

Understanding the interactions between nutrition and the immune system is crucial for adjusting nutrient allowances and dietary formulations to optimize production efficiency. Historically, most nutrition research associated with the immune system has focused on optimizing the immune response. It has been only during the past 10 years that we have begun to understand the influence of the immune system on growth and nutrient requirements.

Physiological changes resulting from an immune challenge

The immune system acts as a sensory organ to detect the presence of antigens (e.g., bacteria, viruses, pesticides, foreign proteins) in the body and to communicate this information to the rest of the body, resulting in a series of behavioral, cellular, and metabolic changes that influence growth and nutrient requirements (Klasing et al., 1987; Klasing, 1988). Three fundamental mechanisms by which the immune system can mediate growth or nutrition related to metabolism include:

- Direct neural connections between immune tissues (thymus, spleen and lymph nodes) and the central nervous system. These peripheral immune responses trigger central nervous system responses such as behavioral adaptations or hormone release from the hypothalamus and pituitary.
- Regulatory linkage between the immune system and the endocrine system. For example, the immune system can cause metabolic changes through hormones normally under pituitary control.
- Release of leukocytic cytokines (monokines and lymphokines), which are hormone-like peptides that are released from macrophage/monocyte lineage cells, and affect metabolic changes from an immune response.

Fortunately, animals possess an elaborate immune system that functions to contain or destroy antigens before life-threatening changes occur. The general response of

TABLE 1: Growth performance and carcass composition of high health (SEW) pigs and average health, conventionally raised pigs (Williams, 1996)

	High Health (SEW)	**Average Health (Conventional)**
Feed Intake, lbs/day		
13-60 lbs BW	2.15	2.00
60-247 lbs BW	5.80	5.56
13-247 lbs BW	4.88	4.62
Daily Gain, lbs/day		
13-60 lbs BW	1.49	1.17
60-247 lbs BW	2.10	1.75
13-247 lbs BW	1.90	1.59
Gain/Feed		
13-60 lbs BW	0.70	0.59
60-247 lbs BW	0.36	0.32
13-247 lbs BW	0.39	0.34
Hot carcass wt., lbs	177.7	175.5
10th rib backfat, in.	1.00	1.16
Loin muscle area, sq. in.	6.14	5.23
Dissected muscle tissue, lbs	100.0	93.4
Dissected fat tissue, lbs	44.2	52.2

the immune system to an antigen is initiated by a release of a series of cytokines (interleukin-1, interleukin-6, and tumor necrosis factor). This cytokine release activates the cellular (i.e., phagocytic) and humoral (i.e., antibody) components of the immune system, lowers voluntary feed intake, and increases core body temperature and body heat production. Fever is associated with an increase in basal metabolic rate of 10–15 % for each 1 degree C above normal.

Nutrient repartitioning

Nutrients are diverted away from productive functions (i.e., lean tissue growth) and toward nutrient demands of the immune system as a result of immune challenge, including vaccination. These metabolic changes increase basal metabolic rate which increases carbohydrate utilization and subsequently increases the energy requirement. Glucose is diverted away from peripheral tissues and toward specific cell populations and tissues responsible for creating an immune response. Cytokines are involved in this process by creating insulin resistance in skeletal muscle and adipose tissue through regulation of insulin receptors and glucose transporters (Moller and Flier, 1992). Consequently, tissue growth rates and body protein synthesis, particularly skeletal muscle, are reduced so that more body proteins can be degraded and contribute to the body's defense for fighting invading antigens. An immune challenge decreases protein synthesis and increases protein degradation rates as a result of reduced feed intake (Johnson, 1997) and an increased need for nitrogen to synthesize acute phase proteins and other immunological products. Amino acid transport and uptake capacity of the liver are increased to meet the increased needs for gluconeogenic substrates and synthesis of acute phase proteins (Augsten et al., 1991). Increased amino acid deamination occurs to increase the amount of gluconeogenic substrates in an effort to satisfy the increased demands for carbohydrate. As a result of increased amino acid deamination, urinary nitrogen excretion increases. Amino acids are also diverted away from lean tissue growth and toward increased leukocytic protein synthesis, increased immune cell synthesis, and increased release of immunocytokines. These changes in amino acid utilization have been shown to lower the amino acid requirements for lysine, methionine + cystine and arginine in chicks, presumably because of less demand for these amino acids for lean tissue growth and a different amino acid profile required for the production of immune products (Klasing et al, 1987). The net results of these metabolic adjustments are reduced body growth rate, less efficient utilization of feed for growth, and potentially fatter carcasses.

Research studies have shown clearly that segregated early-weaned pigs (high health status) eat more feed, grow faster and more efficiently during each stage of production, and produce carcasses that have a higher amount of lean and less fat than conventional pigs. An example of the magnitude of differences in growth performance and carcass composition between SEW and conventionally raised pigs is shown in **Table 1** (Williams, 1996). Because less nutrients are needed to support the immune system of SEW pigs compared to pigs with average health status, more nutrients are needed for meeting the greater capacity for muscle tissue growth. In fact, SEW pigs required 2 to 6

TABLE 2: Estimated lysine intakes (g/day) required to maximize gain/feed in high health (SEW) pigs and average health, conventionally raised pigs at various body weights (Williams, 1996)

Body weight, lbs	High Health (SEW)	Average Health (Conventional)
15	7.9	5.7
55	18.8	15.6
70	17.1	14.1
132	21.9	16.1
194	19.9	16.8
225	19.3	16.1

grams more lysine intake per day at various body weights to maximize gain/feed in this study (**Table 2**).

In addition to the increased requirement for dietary amino acids of high health pigs, other nutrients are also required in greater amounts. Tim Stahly and co-workers at Iowa State University have conducted several experiments to determine the impact of high and moderate levels of antigen exposure on nutrient requirements of pigs. In these studies, high antigen exposure was most often generally defined as production conditions where pigs were reared in conventional, continuous flow facilities; pigs were farrowed in an unsanitized farrowing room, with no administration of antibiotics to pigs postpartum; and pigs were weaned at 19 days of age into an unsanitized nursery occupied by older pigs from the herd of origin. In contrast, moderate antigen exposure was defined as rearing pigs in an SEW system, using pigs farrowed in a sanitized farrowing room; administering antibiotics at 1,3,5,8, and 11 days of age; weaning at 12 days of age; and then housing them in a sanitized nursery away from other pigs.

Dietary fat calories support greater growth rate and efficiency of dietary ME utilization than starch calories in pigs experiencing either moderate or high levels of antigen exposure (Stahly et al., 1996b). Addition of niacin, pantothenic acid, riboflavin, B_{12} and folacin above NRC (1988) estimated requirements resulted in up to 21 and 19% faster growth rates and 10 and 6% less feed required per unit of weight gain in pigs experiencing a moderate and high level of antigen exposure, respectively (Stahly and Cook, 1996b). Pigs with high antigen exposure appear to have a greater need (225% of NRC, 1988) for one or more of the antioxidant vitamins (vitamins A, E, C). The immune system produces toxic free radicals, which are enhanced by cytokines, to assist in killing foreign organisms. However, because of the potential detrimental effects of cytokines and free radicals on pig performance, and the higher amounts produced by pigs subjected to high antigen exposure, the requirement for these antioxidant vitamins was increased to ameliorate the effects of the higher production of free radicals and cytokines (Stahly et al., 1997). Available phosphorus needs for 14 to 60 lb pigs were 1.7 times greater for pigs with moderate antigen exposure compared to high antigen exposure pigs (Stahly and Cook, 1996a). However, linoleic acid requirements do not appear to be higher for high health pigs compared to their moderate health status counterparts (Stahly et al., 1996a).

Other nutritional effects from immunological stress

Lipid and fatty acids

Fatty acids have been shown to regulate cytokine production and synthesis as well as release of prostaglandins. In particular, omega-3 fatty acids have been a main focus of research due to their demonstrated ability to modulate infection and inflammation (Blok et al., 1996). In some species, the release of proinflammatory cytokines resulting from immune stimuli is reduced by omega-3 fatty acids. It has been postulated that conjugated linoleic acid improves growth by displacing linoleic acid in cell membranes and competitively inhibiting the conversion of arachidonic acid to PGE_2 (Cook et al., 1993). This prostaglandin is a potent catabolic inflammatory mediator. However, Spurlock et al. (1997) evaluated the effect of selected fat sources and found no detrimental effect of providing diets with high linoleic acid levels or advantage of providing omega-3 fatty acid enriched diets to immune challenged growing pigs.

Minerals

Serum copper levels increase while serum iron and zinc levels decrease during immunological stress. Iron is required by bacteria for growth; and unless iron in the body is bound by a protein (e.g., transferrin or lactoferrin), susceptibility to infection is increased (Weinberg, 1978). In order to avoid the risk of infection, iron is quickly removed from circulation and made nutritionally unavailable to bacteria and parasites. To prevent further immunological stress, dietary iron levels should not be increased during immunological stress.

What are the effects of nutrition on minimizing the risk of immune challenge in the pig?

Energy

The direct effects of feed (energy) intake on specific immune events are largely unknown. Since vitamin, mineral, and amino acid deficiencies or imbalances depress feed intake, it is difficult to interpret data on nutritional effects and immunocompetence. Both heat and cold exposure reduce passively acquired immunity in newborn pigs which is likely due to reductions in colostrum intake.

Protein

Antibody-mediated immune responses are not substantially affected by moderate protein deficiencies. It is probably more important to study how infectious disease processes affect the nutritional status of the host.

Vitamin E and selenium

When vitamin E and/or selenium are added to nutritionally adequate swine diets, there is generally an increase in the ability of pigs to synthesize antibodies. Supplemental selenium and vitamin E have been shown to increase resistance of sows to MMA (Whitehair et al., 1983a,b).

Iron

Although results are variable among studies, iron imbalances (levels either too high or too low) increase susceptibility to a number of bacterial and parasitic infections.

Vitamin A

Vitamin A supports the functional integrity of epithelial tissues, and a deficiency may cause a reduction in mucous secretion in the respiratory tract leading to penetration of bacteria. Vitamin A deficiency reduces the synthesis of antibodies by ten times.

Zinc

Zinc has an established role in lymphoid cells and resistance to parasitic infections. Coccidial and bacterial infections reduce tissue zinc concentrations.

B-complex vitamins

B-complex vitamins, pantothenic acid, pyridoxine, or riboflavin deficiency leads to a dramatic reduction in antibody synthesis.

Nutrient deficiencies

Nutrient deficiencies rarely occur in pork production operations today because of our increasing understanding of nutrient requirements of pigs under various production conditions as well as our ability to estimate nutrient content, digestibility and bioavailability of ingredients used in swine feeds. However, occasional deficiencies do occur as a result of feed formulation or manufacturing errors as well as under unique circumstances of high productivity, low feed consumption, or other compounding circumstances. In general, energy, amino acid, and water (macro nutrients) deficiencies can be observed quickly because there is limited nutrient storage in the body and pigs have a relatively high requirement for these nutrients to support daily needs. Vitamin and mineral deficiencies generally are not observed until a longer period of time has elapsed because many of these nutrients are stored in the body and are mobilized to compensate for deficiencies in nutrient intake. **Table 3** summarizes general effects of energy, protein and essential fatty acid deficiencies on swine health and performance. **Table 4** summarizes specific mineral deficiency diseases. Vitamin deficiency diseases are summarized in **Table 5**.

TABLE 3: Clinical signs of energy, protein and essential fatty acid deficiencies in swine

	Deficiency Sign								
Nutrient	Slow growth	Reduced appetite	Poor hair and skin condition	Lameness	Diarrhea	Impaired reproduction	Offspring dead or weak at birth	Weakened bone structure	Other (see code)
Energy	X					X			
Protein level		X	X			X	X		2,3
Protein quality (essential amino acids)	X	X	X						3
Essential fatty acids	X	X	X						4

Code:
1. Reduced fatness in proportion to body weight
2. Anemia
3. Poor feed efficiency; overfat carcass
4. Loss of hair; scaly, dandruff like dermatitis, especially of feet and tail

Source: NRC (1968).

TABLE 4: Signs of mineral deficiency diseases

Elements	**Deficiency Disease**
Calcium, Phosphorus	Rickets, Osteomalacia
Magnesium	Tetany
Iron, Copper	Anemia
Copper, Potassium	Ataxia
Zinc	Parakeratosis
Iodine	Hypothyroidism
Manganese	Perosis
Selenium	Hepatosis dietetica, Nutritional muscular dystrophy, Micro angiopathy, Edema

Source: NRC (1968).

Nutrient toxicities

The National Academy of Sciences defines maximum tolerable level as a dietary level that, when fed for a limited period of time, will not impair animal performance and should not produce unsafe residues in human food derived from the animal. Continuous long-term feeding of minerals at the maximum tolerable levels may cause adverse effects. Maximum tolerable levels of minerals and vitamins are affected by the age of the animal. Generally, young pigs are more susceptible to nutrient toxicities than older sows or boars. Furthermore, the multiple mineral interactions as well as mineral-vitamin interactions influence the maximum tolerable levels. **Table 6** summarizes mineral toxicity diseases, and **Table 7** lists the maximum tolerable level of dietary minerals for swine. Vitamin toxicity diseases are not well defined or documented because of the high order of magnitude of supplementation (4 to 10 times the requirement) to achieve a vitamin toxicity status for most vitamins (**Table 8**). Because of the high improbability of feeding toxic levels of most vitamins under practical conditions, vitamin toxicity diseases are not listed.

Vitamin tolerance is defined as the absence of deleterious effects of vitamin intakes above those needed to prevent nutritional deficiency disorders (National Research Council, 1987).

Evaluating status of macro mineral, trace mineral, and toxic mineral status in pigs

Determining mineral status of animals is accomplished by assimilating relevant information from a variety of sources. There is no single best measure for diagnosing mineral deficiencies or toxicities. Thus, the most definitive evaluation of mineral status involves utilizing a combination of data and observations. The NRC (1998) is a key reference to use for establishing a benchmark of mineral intake relative to the requirement. The geographic location (e.g., selenium levels in soil) and production conditions can also be important for assessing status of some minerals. Biochemical measures of samples of feed, body fluids, or tissues are generally the most useful for determining the status of specific minerals, but analyses of other interacting minerals may also be important for a definitive diagnosis (**Table 9** and **10**). Clinical, pathological, and sensory observations are useful in identifying potential deficiencies. However, performance measures such as growth, milk production, reproduction, feed efficiency or health changes may not always be sensitive enough to detect small to moderate mineral deficiencies or toxicities, particularly during a short feeding period.

Water quality

Water quality can have a direct effect on the health and performance of swine in all phases of production and can be highly variable across various geographic areas and production conditions. **Tables 11** and **12** summarize water quality standards for pigs (NRC, 1998).

Special properties of feed ingredients related to pig health

Selection of feed ingredients may play a role in the overall health and performance of pigs apart from the nutrients that a particular ingredient may contribute to the diet. The ingredient may improve the health status of the pig or help the pig endure stresses associated with disease. On the other hand, some feed ingredients may compromise the pig's ability to perform optimally in the presence of stresses induced by disease or the environment. Some ingredients serve a dual role in that they are important sources of required nutrients to swine diets and they more directly influence the pig's ability to cope with disease and other stresses.

Spray dried porcine plasma (SDPP)

Spray dried porcine plasma is used in diets to enhance feed intake and growth rate of newly-weaned pigs. The

TABLE 5: Vitamin deficiency diseases[a]

Vitamin	Deficiency Diseases
Vitamin A	Unsteady gait, Incoordination, Trembling, Spasms, Paralysis, Eye lesions, Reduced growth, Estrus failure, Fetal resorption, Fetus deformities
Vitamin D	Rickets, Osteomalacia, Poor growth, Stiffness, Lameness
Vitamin E (and/or Selenium)	Muscular dystrophy, Hepatosis dietetica, Sudden death of fast growing pigs, Icterus, Difficult locomotion, Peripheral cyanosis, Dyspnea, Weak pulse, Hepatic necrosis, Degenerative myopathy, Edema, Yellow discoloration of adipose tissue, MMA syndrome in sows, Spraddled rear legs in baby pigs, Gastric ulcers, Infertility, Susceptibility to swine dysentery, Poor skin condition
Vitamin K	Impaired blood coagulation, Low prothrombin levels, Increased clotting time, Hemorrhaging
Thiamin	Decreased appetite and body weight, Vomiting, Slow pulse, Subnormal body temperature, Nervous signs, Postmortem heart changes, Sudden death due to heart failure, Anorexia
Riboflavin	Decreased growth, feed consumption, and feed efficiency; Anorexia; Rough hair coat; Dermatitis; Alopecia; Abnormal stiffness; Unsteady gait; Scours; Ulcerative colitis; Inflammation of anal mucosa; Vomiting; Cataracts; Light sensitivity; Decreased immune response; Discolored liver and kidney; Degenerating ova; Degenerating myelin of sciatic and brachial nerves; Premature parturition; Increased stillborn pigs; Anestrus; Cessation of ovarian cyclicity; Hairless newborn pigs
Niacin	Loss of appetite, Retarded growth, Weakness, Digestive disorders, Diarrhea, Stomatitis, Normocytic anemia, Achlorhydria, Exfoliate type dermatitis, Hair loss, Degeneration of nervous system, Inflammatory lesions of gastrointestinal tract, Reduced resistance to bacterial infection
Pyridoxine	Poor appetite, Slow growth, Mycrocytic hypochromic anemia, Dermatitis, Epiletic-like convulsions, Fatty liver, Diarrhea, Rough hair coat, Scaly skin, Brown exudate around eyes, Demyelination of peripheral nerves, Suncutaneous edema, Excessive nitrogen excretion, Increased urinary xanthurenic acid and kynurenic acid
Pantothenic acid	Locomotor disorder of rear legs "goose stepping," Paralysis, Scaly skin and thin hair, Brown secretion around eyes, Dermatosis of shoulder and ears, Necrotic enteritis, ulceration and hemorrhages in the large intestine, Bloody feces, Fatty liver degeneration, Enlarged adrenals, Enlarged heart, Complete reproductive failure
Biotin	Reduced growth and feed conversion; Alopecia; Dry, rough dermatitis with brown exudate; Ulceration of the skin; Inflammation of oral mucosa; Hindleg spacity and cracking of soles and top of hooves; Lameness; Impaired reproduction
Folic acid	Deficiency can be induced by feeding sulfa drugs, Reduced growth, Macrocytic anemia, Leucopenia, Listlessness, Diarrhea, Suboptimal reproductive performance of sows
Vitamin B_{12}	Loss of appetite, Variable feed intake, Dramatic growth suppression, Rough skin and hair coat, Vomiting, Diarrhea, Microcytic normochromic anemia, High netrophil and low lymphocyte counts, Nervous disorders, Thymus and spleen atrophy, Liver and tongue enlargement, Reduced litter size and baby pig survival, Abortions, Low birth weights, Fetal deformities, Late estrus, Fewer corpora lutea and embryos
Vitamin C	Weakness; Fatigue; Dyspnea; Bone pain; Skin, muscle, adipose tissue, and some organ hemorrhaging; Leg weakness
Choline	Unthriftiness, Poor conformation (short legs, pot-belly), Lack of coordination, Loss of joint rigidity, Fatty liver, Spraddled legs of newborn pigs, Reduced conception rate and litter size of sows

[a]Adapted from Hoffmann-La Roche, Inc. 1991. Vitamin Nutrition for Swine.

TABLE 6: Mineral toxicity diseases[a]

Element	Toxicity Disease
Calcium	Parakeratosis (Zn interaction)
Copper	Icterus, Anemia (Fe, Se interaction)
Iron	Rickets, Nutritional Muscular Dystrophy (P, Se interaction)
Selenium	Alkali disease (As interaction)
Sodium	Hypertension (K interaction)
Zinc	Arthritis, gastritis (Cu interaction)
Arsenic	Erythema, ataxia (Se interaction)
Cadmium	Anemia, dermatitis (Fe, Zn interaction)
Cobalt	Anemia (Fe interaction)
Fluorine	Enamel hypoplasia, hyperostosis (Ca, P interaction)
Lead	Ataxia, anemia (Fe interaction)
Mercury	Ataxia, cyanosis, polyuria (Se interaction)
Aluminum	Rickets (P interaction)

[a] National Research Council, 1980.

TABLE 7: Maximum tolerable levels of dietary minerals for swine[a]

Element	**Dietary Level**	**Comments**
Aluminum	200 ppm	Derived by extrapolation from other species. As soluble salts of high bioavailability. Higher levels of less-soluble forms found in natural substances can be tolerated.
Arsenic, inorganic	50 ppm	
Arsenic, organic	100 ppm	
Barium	20 ppm	Derived by extrapolation from other species. As soluble salts of high bioavailability. Higher levels of less-soluble forms found in natural substances can be tolerated.
Bismuth	400 ppm	Derived by extrapolation from other species.
Boron	150 ppm	Derived by extrapolation from other species.
Bromine	200 ppm	
Cadmium	0.5 ppm	Level based on human food residue considerations.
Calcium	1 %	Ratio of calcium to phosphorus is important.
Chromium chloride	1,000 ppm	Derived by extrapolation from other species.
Chromium oxide	3,000 ppm	Derived by extrapolation from other species.
Cobalt	10 ppm	
Copper	250 ppm	
Fluorine	150 ppm	As sodium fluoride or fluorides of similar toxicity. Fluoride in certain phosphate sources may be less toxic.
Iodine	400 ppm	
Iron	3,000 ppm	
Lead	30 ppm	Levels based on human food residue considerations.
Magnesium	0.3 %	Derived by extrapolation from other species.
Mercury	2 ppm	Levels based on human food residue considerations.
Molybdenum	20 ppm	
Nickel	100 ppm	Derived by extrapolation from other species.
Phosphorus	1.5 %	Ratio of calcium and phosphorus is important.
Potassium	2 %	Derived by extrapolation from other species.
Selenium	2 ppm	
Silver	100 ppm	Derived by extrapolation from other species.
Sodium chloride	8 %	Unlimited access to water required at this level
Strontium	3,000 ppm	
Tungsten	20 ppm	Derived by extrapolation from other species.
Vanadium	10 ppm	Derived by extrapolation from other species.
Zinc	1,000 ppm	

[a] National Research Council, 1980.

TABLE 8: Vitamin tolerances of pigs[a]

Vitamin	**Upper Safe Level**	**Comments**
Vitamin A	4x to 10x requirement	Toxic effects at 10x to 1000x requirement
Vitamin D	4x to 10x requirement (>60 d feeding period)100x requirement (<60 d feeding period)	Vitamin D3 is 10x to 20x more toxic than vitamin D2.
Vitamin E	1,000 to 2,000 IU/kg diet75 IU/kg of body weight/day	
Vitamin K (menadione)	1,000x requirement	
Vitamin C (ascorbic acid)	10 ppm	
Thiamin	1,000x requirement	
Niacin	350 mg/kg of body weight/day	
Riboflavin	10x to 20x requirement	100x requirement may possibly be tolerated
Pyridoxine (B6)	1,000x requirement	
Folic acid	Not established	
Pantothenic acid	20 ppm	
Biotin	4x to 10x requirement	
B12	500x requirement	
Choline	2,000 ppm	

[a] National Research Council, 1987.

TABLE 9: Key biochemical analyses for evaluating status of major elements in animals[a]

Element	**Feed**	**Plasma**	**Urine**	**Saliva**	**Bone**	**Other**
Calcium	Ca*, P				Ash, Bone breaking strength	
Phosphorus	P*, Ca (form of P important)	P*			Ash, Bone breaking strength	Response to supplemental P
Magnesium	Mg*, K, N	Mg	Mg*			
Sodium	Na		Na	Na, K		
Potassium	K*					
Chlorine Cl* Cl						
Sulfur	S (form of sulfur is important)					

*Indicates most useful measure(s).

[a] Adapted from Miller (1984).

TABLE 10: Key biochemical analyses for evaluating trace and toxic element status in animals[a]

Element	**Feed**	**Plasma**	**Urine**	**Milk**	**Liver**	**Bone**	**Other**
Iron	Fe (chemical form is important)	% saturation of transferrin, hemoglobin, hematocrit of blood					
Zinc	Zn*	Zn (indicative only with very high dietary Zn or very severe Zn deficiency			Zn	Zn*	Response to supplemental Zn
Copper	Cu, Mo	Cu and ceruloplasmin*			Cu*		
Iodine	I (chemical form is important)			I			
Manganese	Mn*, Ca*, P*						
Selenium	Se*, Vitamin E				Se		Kidney Se, Glutathione peroxidase
Cadmium	Cd*						
Mercury	Hg (chemical form is important)						
Lead	Pb (chemical form is important)		Pb			Pb	
Fluorine	F*		F			F*	Teeth defects*
Arsenic	As						

*Indicates most useful measure(s).

[a] Adapted from Miller (1984).

TABLE 11: Water quality standards for swine[a]

Total Dissolved Solids (ppm)	**Rating**	**Comment**
< 1,000	Safe	No risk to pigs.
1,000 to 2,999	Satisfactory	Mild diarrhea in pigs not adapted to it.
3,000 to 4,999	Satisfactory	May cause temporary refusal of water.
5,000 to 6,999	Reasonable	Higher levels for breeding stock should be avoided.
> 7,000	Unfit	Risky for breeding stock and pigs exposed to heat stress.

[a] NRC, 1998.

TABLE 12: Recommended maximum levels (ppm) of major ions, heavy metals and trace ions in water for livestock based on recommendations of the Task Force for Water Quality Guidelines (TFWQG) and National Research Council[a]

Ions and metals	TFWQG	NRC
Major ions		
Calcium	1,000	--
Nitrate-N + Nitrite-N	100	440
Nitrite-N	10	33
Sulfate	1,000	--
Heavy Metals and Trace Ions		
Aluminum	5.0	--
Arsenic	0.5	0.2
Beryllium	0.1	--
Boron	5.0	--
Cadmium	0.02	0.05
Chromium	1.0	1.0
Cobalt	1.0	1.0
Copper	5.0	0.5
Fluoride	2.0	2.0
Lead	0.1	0.1
Mercury	0.003	0.01
Molybdenum	0.5	--
Nickel	1.0	1.0
Selenium	0.05	--
Uranium	0.2	--
Vanadium	0.1	0.1
Zinc	50.0	25.0

[a] NRC, 1998.

magnitude of growth response is probably greater for younger (10 to 16 days), more immature pigs compared with older pigs (> 21 days) at weaning; however, no one has studied this topic. In addition to being a concentrated source of highly digestible amino acids, SDPP seems to offer some immunological protection to the young pig. Several researchers (Gatnau et al., 1995; Pierce et al., 1995) demonstrated that the beneficial effects of SDPP result from the immunoglobulin fraction (**Table 13**). The immunological protection provided by SDPP appears to elicit a greater performance response in immune-stimulated pigs compared with high health pigs (Coffey and Cromwell, 1995; Stahly et al., 1995). The exact mechanism for the consistent improvement in voluntary feed intake and pig performance is not known. However, these findings suggest SDPP provides some non-specific immunological protection to newly-weaned piglets that typically are weaned at a time when protection from colostral antibodies is waning and their own immune system has not fully matured. One must assume that the IgG's offer non-specific enhancement of the pig's immune status because SDPP is processed from blood collected at slaughter plants. The varying health status of pigs from which blood is collected and the wide array of disease challenges faced by weaned pigs seems to eliminate the possibility that IgG's in SDPP will control a specific disease encountered by the weaned pig that consumes SDPP.

Spray dried egg protein

Spray dried egg proteins are similar to SDPP in that they provide a highly digestible source of essential amino ac-

TABLE 13: Effects of three fractions from SDPP on weanling pig performance[a]

Item	Basal	SDPP Fraction			
		SDPP	Albumin	IgG	Low Molecular Wt.
Daily gain, g	19[d]	134[bc]	79	158[b]	50[d]
Daily feed, g	181[c]	262[b]	244[bc]	273[b]	191[c]
G:F	129[c]	322[b]	217[c]	341[b]	213[c]

[a] Gatnau et al., 1995

[bcd] Means in a row without common superscripts differ ($P < .05$)

ids to the pig. Spray dried egg proteins have not been studied extensively. Early studies indicate a variable response of newly-weaned pigs to spray dried whole egg (SDWE). Owen et al. (1993) reported that partial replacement of soybean meal or SDPP with 6% SDWE depressed pig performance. In a later study at the same institution, Nessmith et al. (1995) found 6% SDWE could replace 3.5% SDPP without detrimental effects on pig performance.

Egg proteins may not possess the same immunological benefits to the pig that SDPP offers because the hen encounters different diseases than the pig. Consequently, antibody titers for important swine diseases are not present in the egg. It may be possible to immunize hens against common swine pathogens to encourage development of specific IgG's against those diseases which would be ultimately included in egg proteins. If this approach is feasible, one could "design" a feed ingredient that would aid in the control of specific swine pathogens. The expense of such a process would likely limit use of such an ingredient to diets for very young pigs.

The immunological benefits of SDPP and other such products are only possible with a gentle drying process. Spray drying allows proteins to be dried without being denatured so that the immunological properties of the protein are maintained. Other drying processes such as vat drying or ring drying are too harsh and destroy the tertiary structure of the immunoglobulins.

Dried porcine solubles (DPS)

Dried porcine solubles is a relatively new feed ingredient. DPS is the dried residue from hydrolyzed porcine intestines that remains after extraction of heparin. Partial replacement of dried whey with 5–6% DPS in diets during the first two weeks postweaning elicited minor improvements in growth rate of nursery pigs (Zimmerman and Sparks, 1996). More interesting was the observation that the improvements in growth rate continued and were of greater magnitude during the subsequent two weeks when all pigs were fed a common diet without DPS. The mechanism for this delayed response is unclear, but possibly DPS hastens maturation of the gut which enhances the pig's ability to digest feed. Potential immunological benefits of DPS have not been investigated.

Rendered animal by-products

Meat and bone meal, meat meal, and other rendered animal by-products are discriminated against because some swine industry professionals perceive an increased risk of disease introduction to swine production units. Brooks (1991) argued that the risk of salmonella introduction via meat meal is far less than cereal grains and soybean because meat meal is produced under strict quality control standards and it is included in diets at relatively low levels. Ingredients of plant origin can be a vehicle for salmonella infection due to contamination with bird and rodent droppings.

Soybean meal

Soybean meal is a staple in the diet of pigs raised in North America. Soybean meal is an inexpensive source of essential amino acids that balances the amino acid deficiencies of the primary dietary energy source, cereal grains. Unfortunately, these benefits are tempered by antinutritional factors present in soybeans. These antinutritional factors include: protease inhibitors, hemagglutinins, goitrogens, saponins, estrogens, cyanogens, oligosaccharides, and antigenic factors (Hancock, 1991). The antigenic factors are particularly troublesome to newly-weaned pigs. Young pigs experience a delayed hypersensitivity to storage proteins present in soybean meal (Li et al., 1990; Dreau et al., 1994). Intestinal villi become shorter and club-like in appearance as a result of the antigenic response to soy proteins (Li et al., 1990). These changes presumably reduce surface area of the intestinal mucosa which likely has negative effects on the gut's ability to absorb nutrients. Li et al. (1991) dosed suckling pigs with dried skim milk, soybean meal or soy protein concentrate to sensitize them to these proteins and then fed diets containing the same protein source immediately postweaning. Pigs dosed with soybean meal and then fed a diet containing soybean meal at weaning had reduced villus height, increased crypt depth, and reduced xylose absorption compared to pigs dosed with and later fed milk proteins or soy protein concentrate (**Table 14**). These same pigs demonstrated reduced rate and efficiency

TABLE 14: Effects of soybean products on gut morphology and xylose absorption[a]

Item	**Milk Protein**	**Soybean Meal**	**Soy Protein Concentrate**
Villus height, mm[bc]	364.2	234.0	309.0
Crypt depth, mm[bc]	198.0	222.4	214.1
Xylose absorption, mg/100 ml[cd]	0.82	0.42	0.61

[a] Adapted from Li et al. (1991).

[b] Milk protein different from others ($P < .01$).

[c] Soybean meal different from soy protein concentrate ($P < .01$).

[d] Milk protein different from soybean meal ($P < .01$).

TABLE 15: Effects of soybean products on starter pig performance[a]

Item	Milk Protein	Soybean Meal	Soy Protein Concentrate
ADG, g			
0-14 d[b]	326	182	208
0-35 d	397	391	396
ADFI, g			
0-14 d[b]	301	251	231
0-35 d	585	605	680
F/G			
0-14 d[b]	.99	1.38	1.14
0-35 d	1.50	1.57	1.70

[a] Li et al. (1991).

[b] Milk protein different from soybean meal (P < .05).

TABLE 16: Growth performance of pigs exposed to soybean meal pre- and postweaning[a]

	SBM[b]				CGM[b]			
	SBM[c]		Placebo		SBM		Placebo	
Item	SBM[d]	Milk	SBM	Milk	SBM	Milk	SBM	Milk
Days 0 to 14								
ADG, g[e]	213	284	216	305	227	301	206	313
ADFI, g[e]	276	285	284	299	280	300	273	304
G/Fe	.77	1.00	.76	1.02	.81	1.00	.75	1.03
Days 14 to 35								
ADG, g[e]	490	389	492	398	519	409	521	413
ADFI, g[e]	782	687	813	736	819	765	809	767
G/F[e]	.63	.57	.61	.54	.63	.53	.64	.54

[a] Adapted from Friesen et al. (1993).

[b] Sow gestation and lactation dietary treatment; SBM = soybean meal and CGM = corn gluten meal.

[c] Preweaning infusion treatment; SBM = soybean meal.

[d] Phase I nursery diet; SBM = soybean meal.

[e] Phase I dietary treatment milk Vs soybean meal (P < .05).

of growth during the first 14 days postweaning (**Table 15**).

An antigenic response to the diet may predispose the newly-weaned pig to gastrointestinal disease. In pigs challenged with pathogenic *E. coli*, feeding a diet that contained antigenic proteins caused diarrhea in 100% of the pigs (Miller et al., 1984). However, no diarrhea was observed when contemporary pigs were fed the same diet that had been enzymatically hydrolyzed to reduce its antigenicity. If susceptibility to E. coli is increased when feeding an antigenic diet to newly-weaned pigs, one may hypothesize that susceptibility to other pathogenic organisms may also be increased.

It is not practical or economical to avoid soybean meal in diets for pigs fed to slaughter weight because of delayed hypersensitivity to the diet. Consequently, pigs must be introduced to soybean meal at some point. Pigs seem to acclimate to the presence of soybean meal in the diet (Li et al., 1991; **Table 15**). Rate and efficiency of growth were reduced in the first 14 days after weaning for pigs fed a diet containing soybean meal. But, for the entire 35-day nursery period, there was no negative impact on growth performance indicating that pigs overcame their sensitivity to soy proteins. Friesen et al. (1993) fed pigs a corn-milk protein diet or a corn-soybean meal diet in the first 14 days postweaning followed by a common corn-soybean meal diet during the subsequent 14 days. They reported improved growth performance for pigs fed the corn-milk protein diet in the first 14 days, but during the second 14-day period these pigs grew slower than their contemporary pigs that received a corn-soybean meal diet beginning at weaning (**Table 16**). Recently, inclusions of 20 to 40% soybean meal in complex diets for pigs weaned at 12 days of age did not negatively impact pig performance (O'Quinn et al., 1997). It would appear that some low level of soybean meal in the first postweaning diet is useful to acclimate the pig to dietary soybean proteins.

TABLE 17: Natural toxins found in feedstuffs fed to swine

Feedstuff	**Toxin(s)**
All grains	Phytate, mycotoxins
Rye, triticale	Trypsin inhibitors, ergot
Milo	Tannins
Buckwheat	Fagopyrin
Potatoes	Solanum alkaloids
Cassava	Cyanogenic glycosides
Soybeans	Trypsin inhibitors, lectins, goitrogens, saponins, phytate, mycotoxins
Cottonseed	Gossypol, tannins, cyclopropenoid fatty acids, mycotoxins
Rapeseed	Glucosinolates, tannins, erucic acid, sinapine
Linseed meal	Linatine, linamarin
Field beans	Trypsin inhibitors, lectins
Lupins	Alkaloids

Natural toxicants in feedstuffs

Many common feedstuffs contain natural toxins that may impair pig performance. However, although their presence is undesirable, knowledge of anti-nutritional factors allows nutritionists to formulate diets around them. **Table 17** is a summary of natural toxins found in grains, tubers, and protein supplements.

Phytate

Phytate is a naturally occurring compound (phosphorus + inositol) in many grains that contain phosphorus of low availability to the pig and may account for as much as 80% of the total phosphorus in grains. Chemical analysis overestimates the phosphorus available to the pig. Phytate combines with other minerals (zinc, iron, manganese) which reduces their availability, and the presence of calcium increases the problem. These adverse effects can be overcome by supplementing the diet with additional calcium, phosphorus and zinc. Additionally, supplementing the diet with the enzyme phytase effectively liberates phosphorus from phytate.

Saponins

Saponins are commonly found in legumes such as alfalfa, soybeans, chickpeas, and beans, and impair pig performance due to bitter taste and irritating effect on the lining of the mouth and gut.

Estrogens

Zearalenone is an estrogenic mycotoxin commonly found in corn. Alfalfa, clover and soybeans can also produce coumestrol which is an estrogenic like substance. Use of alfalfa pellets in sow diets has declined partially because of the possible effects of coumestrol on reproductive performance

Tannins

Tannins elicit their negative effects by binding to proteins and inhibiting protein digestion. Tannins also are present in soybeans, faba beans, sunflower seeds, sorghum and alfalfa and reduce palatability. They can be removed from these feedstuffs, but the process is not cost effective.

Trypsin inhibitors

Trypsin inhibitors are present in soybeans that have not been properly heat processed as well as in alfalfa, rye and barley. Heating soybeans for 15 minutes at a temperature of 212 F will effectively render them inactive in soybeans. Trypsin inhibitors manifest their anti-nutritional effects by binding to protein digesting enzymes (trypsin and chymotrypsin) to render them inactive.

Glucosinolates

Glucosinolates are present in rapeseed, mustard and turnips. Glucosinolates reduce palatability and impair function of the thyroid gland. Low glucosinolate varieties of rapeseed, called canola, have much lower levels of glucosinolates and erucic acid.

Mycotoxins

Mycotoxins are produced by specific molds under specific environmental conditions. Many naturally occurring mycotoxins have been identified, but only a few have been shown to cause significant, detrimental health and performance problems in swine fed contaminated plant based feedstuffs. The maximum tolerable levels and signs of mycotoxicosis in swine are shown in **Table 18**. It is important to remember that the presence of molds in grains does not automatically indicate mycotoxin presence. If clinical signs of mycotoxicosis are observed, it is important to collect a grain or feed sample and send it to a laboratory to determine the presence and level of the suspected mycotoxin(s). Analytical tests for mold spore counts are of little or no value.

TABLE 18: Maximum tolerable level of mycotoxins commonly found in swine feeds[a]

Mycotoxin	Maximum Tolerable Level	Comments
Aflatoxins (B1, B2, G1, G2)	< 20 ppb for human use, dairy feed, feed for immature animals< 100 ppb for breeding swine< 200 ppb for finishing swine (>120 lbs body weight)	Carcinogenic. Immunosuppressant. Acute signs: anorexia, depression, ataxia, epistasis. Chronic signs: reduced feed efficiency, reduced milk production, icterus, decreased appetite.
Zearalenone	< 1 ppm for young growing pigs< 2 ppm for breeding herd< 3 ppm for finishing pigs and young and old boars	Estrogenic effects. Swollen vulvas, vaginal or rectal prolapses in pre-pubertal gilts. Enlarged uterus, swollen or twisted uterus, shrunken ovaries. In boars, testes atrophy, enlarged mammary glands, decreased fertility.
Deoxynivalenol (vomitoxin)	< 5 ppm on grain and grain by-products. DON contaminated feedstuffs should not exceed 20% of the diet. (< 1 ppm in complete feeds)	Reduction in feed consumption and weight gain are inversely proportional to concentration of DON. High concentrations cause feed refusal and vomiting.
T-2 toxin	< 1 ppm	Potent immunosuppressive agent that directly affects immune cells and modifies immune response as a consequence of other tissue damage. Frequent defecation, vomiting, weight loss and feed refusal.
Fumonisin	Not established< 5 ppm (extrapolated from horse data)	Carcinogenic in laboratory tests using rats. Associated with pulmonary edema in pigs.
Ochratoxin	< 200 ppb has been associated with kidney damage in swine	Ochratoxin A is most common and potent. Reduction in growth, feed efficiency, increased mortality, liver and kidney damage.
Ergot	< 200 ppb	Vertigo, staggers, convulsions, temporary posterior paralysis, eventual death. Decreased peripheral blood supply. Reduced growth, tail loss, reduced reproductive efficiency of sows.

[a] Feedstuffs Reference Issue (1997).

Adding fat to swine diets to reduce dust and improve air quality

Air quality in swine confinement facilities is important for worker and pig health. Studies by Donham and Leininger (1984) have shown that 70% of the people that work in swine confinement facilities experienced reduced respiratory health. Dust is a primary pollutant in swine confinement facilities. The primary origin of dust in confinement swine housing is from feed (Curtis et al., 1975; Heber et al., 1988). Several studies have shown that adding soybean oil or fat to pig diets reduces the amount of airborne dust in swine confinement buildings (Chiba et al., 1985; Chiba et al., 1987; Gore et al., 1986; Wilson et al., 1993; Mankell et al., 1995). Only one study failed to demonstrate a significant reduction in airborne dust concentrations when oil was added to swine diets (Welford et al., 1992).

Based on the results from the majority of studies, it is well accepted that adding 1% fat to the diet markedly reduces airborne dust, and further additions of fat to the diet (up to 3% supplemental fat) will further reduce airborne dust levels in swine confinement facilities. Furthermore, Mankell et al. (1995) showed that adding soybean oil to low-bulk density corn diets is effective in reducing dust levels. Mankell et al. (1995) also showed that soybean oil is a more effective dust suppressor when added to complete feed after grinding than when adding it to the corn before grinding, and that feed storage does not reduce the dust suppressing effects of soybean oil added to the feed.

It is impossible to place an economic value on the dust suppression benefits of adding supplemental fat to swine diets. Air quality is extremely important for worker health and respiratory health of the pigs. The cost of adding 1 to 2% supplemental fat for dust control is absorbed in the overall cost of producing pork.

Non-nutritive feed additives and pig health

Additives are included in the diet because they enhance the pig's well being in ways other than providing necessary nutrients.

Antimicrobial agents

The pig's response to antimicrobial agents has not changed significantly in over 30 years of antimicrobial use in swine diets (Zimmerman, 1986). However, there are increasing concerns over development of pathogens that are resistant to antimicrobial agents commonly used in swine diets (Langlois et al., 1984; Mathew et al., 1998). While the exact mechanism of action for many antimicrobials has not been elucidated, it is generally believed that suppression of subclinical infection is responsible for the improvement in pig performance observed when antimicrobials are included in the diet. Antimicrobials tend to be more efficacious in dirty environments compared with more sanitary conditions (Cromwell, 1991).

A summary of many experiments suggests that antimicrobial agents improve growth rate by 16.9% and gain efficiency by 6.9% for young pigs weighing 15 to 55 lb (Cromwell, 1991). This improvement in performance declines as the pig ages such that the improvement in growth rate and feed efficiency was 10.6% and 4.5% for pigs weighing 40 to 100 lb. Antimicrobials may also improve conception rate, survival rate of nursing pigs, and litter size at weaning in problem herds (Cromwell, 1991).

Copper sulfate

Copper sulfate is added to nursery pig diets at 1 to 2 lb per ton to achieve a supplemental copper level of 125 to 250 ppm. At these high levels, dietary copper elicits a performance response similar to that observed when feeding antimicrobial agents. The effects of high dietary copper and antimicrobials are additive. The mechanism of action for copper sulfate has not been clearly defined, but evidence suggests the antimicrobial properties of copper are responsible for enhanced growth. Lower levels of copper (100 to 125 ppm) achieve 70% to 80% of the maximal response and are more sensitive to environmental concerns. Addition of 250 ppm supplemental copper improved ADG and F/G 24% and 9%, respectively, when fed to nursery pigs (Cromwell, 1991). Similar additions of copper improve ADG and F/G of growing pigs 7 and 4%, respectively.

Zinc

Large doses of dietary zinc (2000 to 3000 ppm) in the form of zinc oxide can improve growth performance of nursery pigs. Hill et al. (1996) reported 3000 ppm Zn improved ADG 14%, ADFI 6% and F/G 6% in nursery pigs. In this cooperative study, ten universities reported no additive effects of 3000 ppm zinc and 250 ppm copper on growth performance of nursery pigs (Hill et al., 1996). Like antimicrobial agents and copper sulfate, the mechanism of action for zinc oxide has not been elucidated, but zinc oxide seems to possess antimicrobial properties. Very few controlled experiments to study the interaction between health status of pigs and dietary zinc oxide have been reported. Duhamel et al. (1993) demonstrated that pharmacological levels of Zn can inhibit toxin production of cultured T. hyodysenteriae. Reduced toxin production may be responsible for reduced intestinal damage observed in mice experimentally infected with *T. Hyo* and fed very high levels of Zn (Duhamel et al., 1995). Ward et al. (1996) reported that 250 ppm zinc supplied by an organic zinc compound, zinc methionine, was just as effective as 2000 ppm zinc from zinc oxide in promoting growth of nursery pigs. However, McCalla (1998) did not find any advantages in growth performance when pigs were fed pharmacological levels of another organic zinc compound, Availa-Zn®. Use of organic zinc compounds may improve efficiency of zinc absorption, thus reducing excretion of zinc into the environment. High levels of zinc should be fed only for the first 14 days postweaning to avoid potential toxicity problems that could occur with longer term feeding.

Probiotics

This mixture of living bacteria and/or yeasts is added to the feed with the hope that these favorable organisms will colonize the gut and limit growth of pathogenic organisms. Probiotics are consistently inconsistent (Chesson, 1994). A high degree of inconsistency in responses has been observed when one product is used in different groups of pigs on the same farm or different farms.

Diet acidifiers

Introduction of new, highly acidic inorganic acids has renewed interest in acidification of diets for nursery pigs (Koehler et al., 1996). Bergstrom et al. (1996) reported a 15 to 20% improvement in efficiency of gain when feeding a variety of inorganic acids in the first 7 days postweaning. These acids usually comprise 0.2 to 0.4% of the nursery diet. Presumably, the acidifiers supplement the young pig's limited ability to produce acidic conditions in the stomach. By aiding with acidification of the diet, degradation of dietary protein in the stomach gets a "jump start" which may improve pig performance. The acidic conditions in the diet may limit growth of contaminating organisms (bacteria, molds, etc.) which may improve quality of the diet. This theory has not been evaluated.

Zeolites/clays

Natural zeolites and clays are crystalline minerals mined from the earth that have very small particle size. Their porous structure provides absorptive properties. A wide range of claims have been made for zeolites, most of which have not been documented by controlled experiments. Zeolites may act as a growth promotant possibly working through absorption of toxic ammonia in the gut of the pig. Pond et al. (1988) reported that clinoptilolite, a zeolite, improved growth performance of growing pigs. In contrast, Johnston (1990) found no effect of clinoptilolite mined from a different deposit on growth performance of nursery pigs.

Clays have been used to bind aflatoxin in feed and improve performance of pigs (Schell et al., 1993). Clays also differ in their abilities to bind aflatoxin. Very little research has been conducted to determine if these beneficial properties of clays extend to other mycotoxins such as zearalenone and vomitoxin. These products may have utility in ameliorating the detrimental effects of mycotoxin-contaminated feed. However, be aware that the efficacy of various products against several mycotoxins has probably not been characterized very well.

Conjugated Linoleic Acid (CLA)

Conjugated linoleic acid is a very new feed additive to the swine industry. CLA is a fatty acid that is manufactured from sunflower oil (Skarie, personal communication). The most immediate property of interest to the swine industry is CLA's ability to reduce fat deposition in pigs. Thiel et al. (1998) reported a significant reduction in backfat thickness, and Dugan et al. (1997) observed decreased subcutaneous fat deposition when pigs received CLA in their diets. Thiel et al. (1998) also reported an improvement in efficiency of weight gain. These initial studies look promising, but more extensive study is necessary to determine the consistency of carcass responses to CLA. Certainly, leaner and more efficient market hogs are of interest to both pork producers and packers.

CLA also seems to influence the immune system. Cook et al. (1993) injected both chicks and rats with lipopolysaccharide (LPS) to stimulate an immune response. Experimental animals were offered corn-soybean meal diets with or without 0.5% CLA. Control animals failed to gain body weight or lost weight as a result of the immune stimulation. However, chicks fed CLA continued to grow and rats fed CLA lost 50% less body weight than their contemporaries. These data suggest CLA prevents the catabolic effects of immune stimulation. Thorough studies of CLA effects on the immune system of pigs have not been conducted. But, CLA may play an important role in helping pigs in commercial settings to adapt to disease challenges and remain productive.

Laxative agents

Constipation is usually only a problem in breeding sows. Consequently, laxative agents are used primarily in sow diets. Common laxatives used in swine nutrition include bulk forming laxatives (bran, psyllium husks, methyl cellulose), and osmotic laxatives (magnesium sulfate, potassium chloride; Shurson, 1993). The primary benefit of laxatives is to improve the comfort of sows particularly in the immediate postfarrowing period. The assumption is that if sows are more comfortable, they will consume more feed and be more productive. There appears to be little need for laxatives in gestation diets when feed intake is limited and inappetance is not a problem.

The need for a laxative in diets for lactating sows is debatable. Reese et al. (1992) suggested that laxatives play a minor role in preventing constipation, agalactia, and reduced voluntary feed intake of sows. These authors proposed that management strategies often predispose sows to constipation. These strategies include: 1. Full feeding sows in the last two weeks of gestation, 2. Withholding feed from newly farrowed sows for about 24 hours, and 3. Operating farrowing rooms at temperatures in excess of 70 degrees F. Laxatives should not be part of a standard sow feeding program that is implemented on a continuous basis. Dietary laxatives should be evaluated on a case-by-case basis and used sparingly.

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