National Swine Nutrition Guide

# Nutritional Effects on Swine Nutrient Excretion and Air Quality

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## Introduction

Animal production involves the feeding and care of animals to obtain usable end products, such as meat or milk. Since the efficiency with which animals use nutrients is less than 100%, a portion of the nutrients supplied to the animal is excreted as feces. The end/byproducts of metabolism are excreted in urine. Traditionally, these excreta were used as fertilizers for crops and thus were an integral part of the nutrient cycle.

Over the last decade, animal production has expanded significantly in areas without adequate local feed production. To sustain expanding animal agriculture, feed ingredients were shipped in from major crop producing regions, initiating the import of nutrients, including nitrogen and phosphorus into animal producing regions. Due to the bulk of animal manure relative to its weight, shipping it to the feed producing regions for use as a fertilizer was not economically viable. Alternative methods to deal with manure were thus sought. Some are focused on different processing and storage techniques after manure production, while others deal with reducing the excretion of nutrients in manure. This factsheet outlines some of the underlying principles for modifying pig diets with the objective of reducing nutrient excretion and ammonia and odor emissions.

## Objectives

Discuss production methods of reducing nutrient excretion and odor emission through:

- Reducing feed waste
- Improving nutrient yield of feed
- Using precision nutrition for each stage of growth
- Reducing ammonia
- Reducing odor and dust
- Increasing water consumption

## Feed Wastage

Poor feeder design and presentation of feed can lead to the wastage of animal feed. Gonyou and Lou (1998) [1] reported that feed wastage was typically 5% to 6% but much larger ranges have been reported for field conditions (1.5% to 20%). Although little research has been performed to evaluate the contribution of feed wastage to nutrients in manure, it cannot be ignored.

Feed wastage is strongly influenced by the presentation of the feed. Mash feed tends to cling to the animal's chin and nose, ultimately leading to waste. Each time the pig leaves a feeder it takes 1.5 grams of feed with it [1]. Given that the pig typically accesses the feeder 60 times per day, this theoretically could amount to wasting 90 grams (0.2 lbs) of feed. Pigs also tend to root through the feed, which in poorly designed feeders leads to the waste of 3.4% of feed [1]. Pelleting feeds reduces both forms of feed wastage. It has been estimated that pelleting reduces feed wastage by approximately 5% [2].

Traditional recommendations for controlling feed wastage are to select feeders that are designed such that it is more difficult to push feed out of the feeder, and even more importantly, to adjust the feeder so that only a small amount of feed is present in the feeder at any one time. This requires that feeders are easy and accurate to adjust. A general guideline is that feeders should be adjusted and maintained so that only 50% of the bottom of the feeder is covered with feed, not only preventing feed wastage but also reducing the spoilage of feed.

Since wasted feed generally falls into the manure storage areas, its contribution to manure can be estimated by making some assumptions. For example, if feed wastage is 5% on average during the grow-finish phase, and the animal utilizes approximately 30% of the N fed, then feed wastage contributes 7% of the N in manure. For minerals such as copper, zinc, and phosphorus, the contribution of feed waste to manure is similar. For carbohydrates, however, the contribution is much different. The animal digests approximately 85% of the carbohydrates in a typical diet, and feed wastage at 5% would then contribute 25% of the carbohydrates in the manure. Although carbohydrates are not considered pollutants, they are a substrate for fermentation, which leads to the production of malodorous compounds, such as volatile fatty acids.

## Improving Nutrient Utilization from Feed

Feces are partially produced because feed is not 100% digestible. For example, amino acids in typical feedstuffs have a digestibility ranging between 60% and 90%, while phosphorus digestibility ranges from 20% to 70% (Table 1). For minerals such as copper and zinc, digestibility typically ranges from 10% to 45% (Table 2). Therefore, it is important to take the digestibility of nutrients in feed ingredients in consideration when formulating diets, and the NRC recommends using true ileal digestibility values for amino acids and availability for phosphorus [3].

When selecting feed ingredients, it is crucial to select ingredients that have high nutrient digestibilities. Formulating diets with least-cost formulating software that uses digestible nutrients in formulation will assist in selecting those ingredients that have a high digestibility within the range of what is economically attractive.

**Table 1. Typical content of protein and phosphorus in commonly used feed ingredients and their digestibility in swine.[1]**

| Ingredient | Protein | | Phosphorus | |
|---|---|---|---|---|
| | Digestibility % | Content % | Digestibility % | Content % |
| Corn | 85 | 8.5 | 14 | 0.28 |
| Soybean meal, 48% CP | 87 | 49 | 23 | 0.69 |
| Soybean meal, 44% CP | 84 | 45.6 | 31 | 0.65 |
| Wheat | 89 | 13.3 | 50 | 0.37 |
| Wheat bran | 75 | 15.7 | 29 | 1.2 |
| Barley | 85 | 10.6 | 30 | 0.36 |
| Sorghum | 83 | 9.2 | 20 | 0.29 |
| Meat and bone meal | 84 | 49.1 | 95 | 4.98 |
| Poultry byproducts | 77 | 57.7 | 95 | 2.41 |
| Fish meal | 88 | 62.9 | 95 | 2.2 |
| Dicalcium phosphate | - | - | 100 | 18.5 |

[1]Adapted from NRC (1998) [3].

**Table 2. Digestion and retention of nitrogen, phosphorus, copper, and zinc by different classes of swine.[1]**

| Mineral | Nursery | Finishing | Gestating | Lactating |
|---|---|---|---|---|
| Nitrogen | | | | |
| Digested, % | 75 to 80 | 75 to 88 | 88 | - |
| Retained, % | 40 to 50 | 30 to 50 | 35 to 45 | 20 to 40 |
| Phosphorus | 20 to 70 | 20 to 50 | 30 to 45 | 10 to 35 |
| Digested, % | 20 to 60 | 20 to 45 | 20 to 45 | 20 |
| Retained, % | | | | |
| Zinc | | | | |
| Digested, % | 20 to 45 | 10 to 20 | - | - |
| Copper | | | | |
| Digested, % | 18 to 25 | 10 to 20 | - | - |

[1]Adapted from Kornegay and Harper (1997) [4]

New sources of highly digestible feedstuffs are being developed by crop breeders, either using classical breeding techniques or through genetic modification of crops. Examples of such products are low-phytate corn and low-stachyose soybeans. Low phytate corn can reduce phosphorus excretion from 13 to 50% [5-7]. When diets were formulated based on available phosphorus (rather than total P) using low phytate corn, phosphorus excretion was reduced by 35 to 40% [6].

One method of reducing the manure produced is to improve the digestibility of feeds, for example, through technological treatments of the feeds or through the addition of enzymes to the feed. For each 1% improvement in digestibility, nitrogen excretion per lb of meat produced decreases by 0.65%.

Examples of technological treatments to improve digestibility include particle size reduction (grinding, roller milling), pelleting, and expanding. Wondra et al. (1995) [8] demonstrated that a uniform particle size of approximately 400 microns leads to a better nutrient digestibility than coarsely ground material (although ulcers may increase with fine particle size). For practical purposes, a particle size of 700 microns is commonly recommended.

Animals prefer pelleted feed over mash feed and pelleting improved feed efficiency by 8.5% (largely due to a reduction in feed wastage), and protein digestibility by 3.7% [2]. Expanders and extruders are used mainly to provide flexibility in ingredient selection and to improve pellet quality rather than to improve nutrient digestion. Due to the high temperature in these processes, their effect on digestibility depends strongly on the composition of the feed (and digestibility can actually decrease in some cases).

Feed enzymes that are commonly used to improve nutrient digestibility are phytase, xylanase, and beta-glucanase [9]. Xylanases and beta-glucanases are enzymes that are used to degrade nonstarch polysaccharides (a soluble dietary fiber fraction) present in cereals such as wheat and barley. The pig does not secrete these enzymes and, therefore, does not have the capability to digest and use nonstarch polysaccharides, resulting in a loss of usable energy from the diet. Because these nonstarch polysaccharides can trap other nutrients, such as protein and minerals, they also increase mineral excretion. The addition of xylanase and/or beta-glucanase to cereal-containing diets can improve digestibility and feed efficiency. An improvement in ileal amino acid digestibility of 9% was observed when beta-glucanase was supplemented to diets containing hulless barley [10]. In addition, ileal digestibility of energy was improved by 9.6% by enzyme supplementation. When beta-glucanase was supplemented to wheat-based diets, ileal amino acid and energy digestibility were numerically increased by 5.6% and 6.6%, respectively [10]. Inclusion of fiber-degrading enzymes (xylanase) in a highfiber diet improved dry matter and energy digestibilities by 2 and 3%, respectively, and reduced fecal production by 10% [11]. Thus, using enzymes in least cost diet formulation could increase the availability of nutrients to the animal by increasing digestibility and reducing the amount of nutrients excreted.

Proteases, as the name implies, are used to degrade proteins. The use of proteases in animal feeds is not yet widespread and little research has been conducted to evaluate their effectiveness. Caine et al. (1997) [12] tested the effects of proteases on the ileal digestibility of amino acids in soybean meal and reported no positive results. With the advancements in enzyme-producing technology and a better understanding of the role of enzymes in animal nutrition, proteases, and other enzymes (e.g., pentosanases, cellulases, and hemicellulases) are likely to find a place in swine nutrition and can ultimately enhance nutrient retention and reduce nutrient excretion. The potential role of enzyme supplementation on odor emission has not been evaluated.

Phosphorus in commonly used feed ingredients such as corn, wheat, and soybean meal is predominantly present in the form of phytate. Phytate is a structural molecule containing phosphorus, but pigs are unable to use this phosphorus because they cannot break down the phytate molecule. In corn, approximately 90% of the phosphorus is present as phytate, while in soybean meal, approximately 75% of the phosphorus is present as phytate. Since this phytate complex is digested poorly in swine, most of the phosphorus contained in the feedstuffs will end up in the manure. To meet the animal's phosphorus requirement, inorganic phosphorus such as dicalcium phosphate is traditionally added to the diet because this source is high in level and availability of phosphorus. The use of an enzyme, phytase, has initiated a new era in the battle to reduce nutrient excretion. It breaks down most of the phytate complex, releasing phosphorus as well as other nutrients (such as zinc and amino acids) bound by it. Phytase improves phosphorus digestibility in a typical swine diet from 30% to 50% [13]. The use of phytase resulted in a reduction in phosphorus excretion by 32% under practical conditions in nursery pigs [14].

The impact of improving the digestibility of feeds on odor emission has not been extensively studied. Because most odors are the fermentation products of remnants of the digestive process, we can expect that improving digestibility reduces odor emission.

## Interaction of Feed with the Animal

Pigs have to make an effort to obtain the nutrients from their feed. This effort consists of the production of digestive enzymes and losses of cells of the intestinal tract (so called endogenous losses), and it is also linked to the efficiency with which the pig can produce these enzymes and proteins. Together, these losses account for approximately 18% of the dietary nitrogen intake and 26% of the manure nitrogen produced.

To reduce these losses, feedstuffs should be selected that are easily digested. Currently, no large databases exist to identify feedstuffs that are easily digestible, although several research groups are working on such databases. Research thus far has shown that dietary fiber is of major importance in determining the ease of digestibility of feedstuffs, with high fiber content making digestion more difficult [15, 16].

Anti-nutritional factors, such as trypsin inhibitors, reduce the efficacy of digestive enzymes, forcing the animal to produce more enzymes and thus increasing nutrient excretion. Therefore, feedstuffs should be selected that are low in anti-nutritional factors such as trypsin inhibitors (most anti-nutritional factors are routinely analyzed by commercial laboratories).

## Precision Nutrition

Pigs require nutrients in precise amounts for maximum growth and for maximum efficiency of growth. Providing excess nutrients will result in increased excretion, whereas providing less nutrients than required will result in suboptimal growth. Thus, for optimum efficiency of nutrient use, it is important to feed pigs the correct quantity of available nutrients in an ideal amount and ratio.

Pigs are often fed slightly above their nutrient requirements to provide a margin of safety or simply because that diet is the cheapest to manufacture. Feed formulation packages typically determine which combination of dietary ingredients meets the nutritional requirements of the animals at a minimum cost. Such diets, however, are not necessarily optimized from an economic point of view (as they ignore the law of diminishing returns and only take diet cost into consideration). In addition, they are not optimized from an environmental point of view. Especially in cases where disposal of nutrients is costly, having a slightly less nutrient dense diet leading to suboptimal performance but with greatly reduced nutrient excretion may actually be economically attractive.

The result of current least-cost diet formulation software is that the protein content of a typical swine ration could be reduced three percentage points (e.g., from 16% to 13%; achieved by replacing, e.g., soybean meal with synthetic amino acids and corn) without negative effects on animal performance [17]. Formulation of pig diets should be done based on amino acid requirements (amino acids are the building blocks of proteins and lean tissue production), because pigs need amino acids both for maintenance and for growth. The amino acid requirement for maintenance is a function of the animal's weight; a baby pig requires very little, while a market-weight pig requires approximately 25 times as much. The amino acid requirement for growth is primarily determined by the specific composition of the proteins in muscles and organs. By combining the amino acid profile required for growth with that required for maintenance, the animal's amino acid requirement can be calculated [18]. This profile is expressed relative to lysine, which is the first limiting amino acid in swine diets (Table 3).

**Table 3. Ileal true digestible amino acid patterns for pigs in three different weight classes.**[1]

| Amino Acid | Ideal Pattern, % of lysine | | |
|---|---|---|---|
| | 10 to 45 lbs | 45 to 110 lbs | 110 to 240 lbs |
| Lysine | 100 | 100 | 100 |
| Threonine | 65 | 67 | 70 |
| Tryptophan | 17 | 18 | 19 |
| Methionine + Cystine | 60 | 62 | 65 |
| Isoleucine | 60 | 60 | 60 |
| Valine | 68 | 68 | 68 |
| Leucine | 100 | 100 | 100 |
| Phenylalanine + Tyrosine | 95 | 95 | 95 |
| Arginine | 42 | 36 | 30 |
| Histidine | 32 | 32 | 32 |

[1] Adapted from Baker (1996) [18].

Thus, by using this concept and by using multiple (cost-effective) ingredients, the protein content of the diet can typically be reduced without sacrificing performance. A simple example is to replace some of the soybean meal in a corn-soybean meal diet with synthetic lysine (while meeting the requirement for all other amino acids). For the diets examined, this would reduce the protein content in the diet by approximately 1.5 percentage points. Making tryptophan, threonine, and methionine available at competitive prices can reduce the protein content of the diet even further. Many of the synthetic amino acids are currently being used in diet formulation of progressive pork enterprises. Synthetic ingredients provide an obvious example of the benefit of using multiple ingredients in diet formulation, but ingredients such as meat and bone meal, wheat, or barley could provide similar benefits.

A reduction in the protein content of the diet can exert a large impact on nitrogen excretion in manure (Table 4). For each percentage point that nitrogen is reduced in the feed, nitrogen excretion is reduced by 10% to 11% [20, 21]. When reducing nitrogen excretion through precision nutrition, ammonia emission is reduced in similar proportions.

The potential benefits of the precision nutrition concept with low-protein diets on the concentration of odorous compounds in manure was clearly demonstrated, indicating that minimizing a diet's protein content not only substantially reduces nitrogen in the manure but also reduces odor compounds in the manure [22]. When comparing a commercial diet (18.9% protein) with a least-cost formulated low protein diet (14.0% protein) in finisher pigs, p-cresol (the main odor-causing agent in swine manure [23]) decreased 43%; other odorous compounds measured decreased anywhere from 40% to 86%, depending on the compound.

To reduce overfeeding, it is important to understand the animal's nutritional requirements, the nutritional availability in feedstuffs, and the methods used to make the animal feeds. The nutritional requirements of animals are typically defined under laboratory-type conditions; animals are generally well cared for, and environmental conditions are maintained as close to optimum as possible. These requirements, though, do not necessarily translate to field conditions. As indicated previously, the nutritional requirements of pigs can be calculated if the the animal's weight and actual protein growth are known [3]. Producers should attempt to obtain estimates of lean gain of pigs produced on their farm to better define the nutritional requirements of their animals and under their production environment.

**Table 4. Effect of adding crystalline amino acids to a corn-soybean meal (C-SBM) diet on the land application area required for a 1,000-head capacity pig-finishing facility. Nutrient use in crop production assumed a corn (170 bushels/acre) and soybean (50 bu/acre) rotation.[1]**

| Diet Options | Manure N Excretion, lb N/yr | Available N After Losses, lb N/yr | Land Requirement for Managing N, acres |
|---|---|---|---|
| **Systems that conserve nutrients (manure storage and incorporation during application)[5]** | | | |
| C-SBM[2] | 26,300 | 21,300 | 130 |
| C-SBM + lysine[3] | 22,900 | 18,500 | 113 |
| C-SBM + lysine, tryptophan, threonine, and methionine[4] | 16,600 | 13,400 | 82 |
| **Nutrient disposal system (anaerobic lagoon and pivot irrigation)[6]** | | | |
| C-SBM[2] | 26,300 | 4,000 | 25 |
| C-SBM + lysine[3] | 22,900 | 3,400 | 22 |
| C-SBM + lysine, tryptophan, threonine, and methionine[4] | 16,600 | 2,500 | 16 |

[1] Source: Reese and Koelsch (1999) [19]
[2]Dietary crude protein level was 17.9%, 16.5%, 15.1%, and 13.0% for 45-80lb, 80-130lb, 130-190lb, and 190-250lb pigs, respectively.
[3]Dietary crude protein level was 16.4%, 14.9%, 13.6%, and 12.1% for 45-80lb, 80-130lb, 130-190lb, and 190-250lb pigs, respectively.
[4]Dietary crude protein level was 14.0%, 12.6%, 11.1%, and 9.6% for 45-80lb, 80-130lb, 130-190lb, and 190-250lb pigs, respectively.
[5]80% of the nitrogen is conserved.
[6]20% of the nitrogen is conserved in the wastewater to be pumped.

An animal's nutrient requirements change with age, sex, and growth potential. If the objective is to minimize nutrient excretion, then it becomes important to feed diets that are formulated to match the animal's nutrient requirement. Examples of this are split-sex feeding and phase feeding. For split-sex feeding, differences in nutrient requirements among gilts, barrows, and possibly boars are taken into consideration. Barrows typically have a higher feed intake capacity without a larger potential for lean gain, and thus diets should be fed with somewhat lower amino acid content.

Phase feeding refers to feeding programs that match the animal's nutrient requirements as they change with the animal's age or size. To minimize nutrient excretion, the animal's diet should be changed continuously to match its requirements. Going from a one-phase feeding program between 50 pounds and 250 pounds to a two-phase feeding program should reduce nitrogen excretion by 13%, while going to a three-phase feeding program should reduce nitrogen excretion by 17.5%.

From a practical perspective, it is not feasible to change the feed often, e.g., weekly, unless feeding equipment is available that is designed for this purpose. Feed costs savings can be achieved by feeding in multiple phases (Table 5) and based on this information, pork producers should select the number of phases that fit their operation.

**Table 5. Savings in feed costs with phase feeding in finishing pigs. From Pork 98.**

| Number of Phases | Diet Cost/Pig | Savings over 2-phase program | Increase in Savings per Additional Diet |
|---|---|---|---|
| 2 | $42.44 | -- | -- |
| 3 | $41.41 | $1.14 | $1.14 |
| 4 | $41.01 | $1.54 | $0.40 |
| 5 | $40.67 | $1.88 | $0.34 |
| 6 | $40.43 | $2.12 | $0.24 |
| 9 | $40.10 | $2.45 | $0.11 |
| 12 | $39.90 | $2.65 | $0.06 |

To feed pigs precisely, not only must the nutritional requirements of the pig and the nutrient levels and availability of the feed be fully understood, but also the capabilities of feed manufacturers to make these feeds. In general, feed manufacturers limit quality control to the measuring of nitrogen (crude protein). Nitrogen, however, correlates poorly with the available amino acid content of feedstuffs [24], and feed manufacturers are, therefore, inclined to produce feed with a higher degree of variation than desirable for precision nutrition. Reducing the variation by using appropriate quality control measures would result in a 13% to 27% reduction in N excretion [24]. A prime example of such a quality control measure is to assess the nutritional value of each batch of a feedstuff, using, e.g., infrared spectroscopy, and then formulate feeds based on this nutritional value.

Another potentially serious problem is the inability of some feedmills to properly weigh out ingredients. This problem is mainly precipitated by the use of scales that are not precise enough for accurately weighing ingredients. Under practical conditions, this problem leads to an increase in weighing variation and typically overdosing of ingredients [25].

Phosphorus is commonly fed at levels above the requirement of the pig to allow for a safety margin and to account for different production circumstances. Because it is likely that the land application rates of manure will be based on phosphorus load in the near future, swine producers may want to closely monitor the phosphorus intake and excretion of their pigs.

Phosphorus requirements can be determined to maximize bone strength or to maximize performance. The maxima for each of these parameters is different by approximately 0.1% dietary phosphorus, with maximum bone strength requiring more phosphorus. Especially for pigs targeted for slaughter, it may not be necessary to optimize the dietary phosphorus content for bone strength, which would lead to a large reduction in phosphorus excretion (Table 6). Care, however, should be taken to avoid jeopardizing the welfare of the animals.

**Table 6. Effect of reducing dietary phosphorus level by 0.1% in corn-soybean meal diets (CSBM) on the land application area required for a 1,000-head capacity pig-finishing facility. Nutrient use in crop production assumed a corn (170 bushels/acre) and soybean (50bu/acre) rotation.[1]**

| Diet Options | Manure P Excretion, lb $P_2O_5$/yr | Available N After Losses, lb $P_2O_5$/yr | Land Requirement for Managing P, acres |
|---|---|---|---|
| **Systems that conserve nutrients (manure storage and incorporation during application)[4]** | | | |
| Normal C-SBM[2] | 13,000 | 13,000 | 257 |
| Reduced P diet[3] | 8,900 | 8,900 | 177 |
| **Nutrient disposal system (anaerobic lagoon and pivot irrigation)[5]** | | | |
| Normal C-SBM[2] | 13,000 | 4,600 | 90 |
| Reduced P diet[3] | 8,900 | 3,100 | 62 |

[1]Source: Reese and Koelsch (1999) [19]
[2]Dietary phosphorus level in the diets was 0.60%, 0.55%, 0.50%, and 0.45% for 45-80lb, 80-130lb, 130-190 lb, and 190-250lb pigs, respectively.
[3]Dietary phosphorus level in diets was 0.50%, 0.45%, 0.40%, and 0.35% for 45-80lb, 80-130lb, 130-190lb, and 190-250lb pigs, respectively. Dietary phosphorus level was reduced by removing 11lb of dicalcium phosphate per ton of complete feed and substituting normal corn for low-phytate corn or adding phytase to normal corn-based diets.
[4]100% of the phosphorus is conserved.
[5]35% of the phosphorus is conserved in the wastewater to be pumped.

Copper and zinc are elements which also should be considered from an environmental perspective [26]. The practice of feeding levels of copper and zinc well in excess of the requirement (approximately 20 times the requirement) in nursery pigs is common to increase growth performance of pigs. The opportunity to reduce zinc and copper excretion by eliminating these high copper and zinc levels in the nursery phase is substantial [27]; however, lowering these growth-promoting levels to reduce excretion may reduce pig performance.

Even if growth promoting levels of Zn and Cu are eliminated, a further reduction of micro-minerals below levels that are commonly fed in the industry can have a significant impact on mineral excretion. Zinc and copper concentrations commonly supplemented to gilt diets can be greatly decreased without affecting pig performance from weaning through development [28]. Reducing supplemental concentrations of zinc and copper in pig diets decreased fecal concentrations of copper and zinc by approximately 50% in that study. Similarly, excretion of zinc, copper, iron, and manganese could be reduced substantially without affecting performance in finishing pigs under commercial conditions by feeding lower levels of zinc, copper, and iron than commonly used in the swine industry [29].

## Nutritional Interventions Targeting Ammonia

Ammonia emission is an environmental problem due to its nitrifying and soil-acidifying properties and its potential to affect human and animal health. Ammonia emission can be reduced by precision nutrition. Reducing protein by one percentage point reduces ammonia emission by approximately 10% [30, 31].

Ammonia emission can also be reduced by decreasing the pH of urine and manure. In housing systems, a large portion of ammonia emission is derived from urine deposited on manure-coated slats rather than from the manure in the pits and changing the pH of urine is most effective in reducing immediate ammonia emissions [32]. Replacing $CaCO_3$ (limestone) in the diet with $CaSO_4$ (gypsum), $CaCl_2$ (calcium chloride), or calcium benzoate (not yet an approved feed ingredient), caused ammonia emission to be reduced by 30%, 33%, and 54%, respectively [33]. The drop in urinary pH was approximately 1.3 pH units for $CaSO_4$ and $CaCl_2$, while the drop was 2.2 pH units for calcium benzoate.

Using benzoic acid for this purpose actually improved feed conversion (from 2.92 to 2.83) while decreasing ammonia emission by 40% [34]. Adipic acid and phosphoric acid (which can substitute for other phosphorus sources in the diet) alone and together effectively reduced urine pH and significantly reduced ammonia emissions (van Kempen, unpublished).

## Nutritional Interventions Specifically Targeting Odor and Dust

Odors are produced when organic material is fermented. Carbohydrates yield volatile fatty acids such as butyric acid. Proteins yield volatile fatty acids, phenolics such as para-cresol and skatole, mercaptans such as hydrogen sulfide and ethylmercaptan, and amines such as putrescine and cadaverine. One solution to decreasing odor is thus to decrease the availability of fermentable material, particularly protein.
As outlined above, highly digestible ingredients and low-protein diets are key solutions to reducing odor [35].

The dietary sulfur content is another factor affecting odor. Sulfur can be used to form mercaptans, compounds that are very malodorous and have a very low odor threshold (thus a very low concentration is detectable by the human nose). Sulfur is contained in amino acids such as cysteine, methionine, and taurine, and excesses of these amino acids should be avoided. Many minerals are provided in diets as sulfur salts; such salts are typically inexpensive and of acceptable availability. The sulfur, however, contributes to odor, and alternative sources of those minerals should be considered where odor is of concern [36].

Dust is derived from animal skin, feed, and manure and can serve as a carrier for odors. Skin health is strongly affected by nutrition, although typically no nutritional problems are present that would increase dust from skin. Feed dust can be reduced through pelleting and through the addition of fat to the diet. In addition, feed should be handled such that dust is minimized. For example, feed should not be allowed to drop over a large distance in the feeder. Also, presenting feed in wet form or in a wet-dry feeder reduces dust. Fecal material, once it dries, can lead to dust as well. Fecal material can be made wetter and stickier simply by adding nonstarch polysaccharides to the diet, such as xylans and betaglucans (commonly found in cereal grains such as wheat and barley). Such a strategy, simply to reduce dust, however, is not recommended because it will decrease protein digestion and likely increase odor.

## Water (The Overlooked Nutrient)

If manure is to be transported for land application as a fertilizer or is to be processed, it is important to reduce the manure's water content, thus decreasing the volume of manure and thereby minimizing transport or processing costs. Several common-sense management practices should be followed to minimize water use. For example, waterers should be routinely maintained and water leaks should be fixed immediately. When cleaning, barns should be soaked with a foaming agent and subsequently cleaned with a high-pressure washer.

Drinking water can be supplied to pigs via many different routes. Conventional water nipples often do not efficiently deliver water to the pigs. Installing cups under the drinkers will reduce water usage, however, they will need to be managed properly to keep them clean. Some of the newer water nipples have been designed specifically to reduce water usage, and reductions in water consumption are notable [37]. For example, changing the water supply from a drink cup to a feeder with an integrated drink nipple resulted in a 33% decrease in manure production (from 400 gallons to 250 gallons per animal place per year) [38].

Alternatively, feed systems can be used in which water is incorporated. Wet-dry feeders limit the waste of water, while typically improving gain and animal health. Liquid-feeding systems allow for the accurate control of the feed-to-water ratio, providing a well-controlled means for minimizing water wastage. It should be noted that concentrated manure may be more difficult to pump, and when changing the watering and feeding system, care should be taken that the manure handling system is changed accordingly.

## Summary

The strong possibility of stricter environmental regulations for hog operations requires the swine industry to focus on the reduction of nutrient excretion and odor emissions. Decreasing nutrient excretion can be accomplished by decreasing feed wastage and increasing nutrient digestibility. It is essential that producers work with their feed supplier to monitor both feed quality and consistency. Improper diet formulation not only increases nutrient excretion and odor emissions, but more importantly costs the producer money in lost feed efficiency. Being proactive in these measures will help to ensure that the pig is receiving the optimum diet at the correct stage of production. In turn, this allows the pig to grow at maximum efficiency while excreting the minimum amount of nutrients possible.

## References


1. Gonyou, H.W., and Lou, Z. 1998. Grower/finisher feeders: design, behaviour and performance. Prairie Swine Centre, Inc., Saskatoon. Monograph 97-01, 77.
2. Vanschoubroeck, F., L. Coucke, and R. van Spaendonck. 1971. The quantitative effect of pelleting feed on the performance of piglets and fattening pigs. Nutr. Abstr. Rev. 41:1-9.
3. NRC. 1998. Nutrient requirements of swine (10th ed.). National Academy Press. Washington, D.C.
4. Kornegay, E. T., and A. F. Harper. 1997. Environmental nutrition: nutrient management strategies to reduce nutrient excretion of swine. Prof. Anim. Sci. 13:99-111.
5. Pierce, J. L., G. L. Cromwell, T. E. Sauber, D. W. Rice, D. S. Ertl, and V. Raboy. 1998. Phosphorus digestibility and nutritional value of low-phytic acid corn for growing pigs. Midwestern Section Meeting of the American Society of Animal Science, Des Moines, IA:58.
6. Pierce, J. L., and G. L. Cromwell. 1999. Performance and phosphorus excretion of growing-finishing pigs fed low-phytic acid corn. Midwestern Section Meeting of the American Society of Animal Science, Des Moines, IA:35.
7. Veum T.L., D.R. Ledoux, V. Raboy, and D.S. Ertl. 2001. Low-phytic acid corn improves nutrient utilization for growing pigs. J. Anim. Sci. 79:2873-2880.
8. Wondra, K.J., J.D. Hancock, K.C. Behnke, and C.R. Stark. 1995. Effects of mill type and particle size uniformity on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. Anim. Sci. 73:2564-2574.
9. Bedford, M. R. 2000. Exogenous enzymes in monogastric nutrition - their current value and future benefits. Anim. Feed Sci. Techn. 2000, 86:1-13.
10. Li, S., W. C. Sauer, S. X. Huang, and V. M. Gabert. 1996. Effect of b-glucanase supplementation to hulless barley- or wheat-soybean meal diets on the digestibilities of energy, protein, b-glucans, and amino acids in young pigs. J. Anim. Sci. 74:1649-1656.
11. Moeser, A. J., and T. A. T. G. van Kempen. 2002. Dietary fibre level and xylanase affect nutrient digestibility and excreta characteristics in grower pigs. J. Sci. Food Agric. 82:1606-1613.
12. Caine, W.R., W.C. Sauer, S. Tamminga, M.W.A. Verstegen, and H. Schulze. 1997. Apparent ileal digestibilities of amino acids in newly weaned pigs fed diets with protease-treated soybean meal. J. Anim. Sci. 75:2962-2969.
13. Mroz, Z., A.W. Jongbloed, and P.A. Kemme. 1994. Apparent digestibility and retention of nutrients bound to phytate complexes as influenced by microbial phytase and feeding regimen in pigs. J. Anim. Sci. 72:126-132.
14. van der Peet-Schwering, C. 1993. Effects of microbial phytase in the feed on growth performance of weaned piglets. Research Institute for Pig Husbandry, Rosmalen, the Netherlands.
15. Schulze, H., P. van Leeuwen, M.W.A Verstegen, J. Huisman, W.B. Souffrant, and F. Ahrens. 1994. Effect of level of dietary neutral detergent fiber on ileal apparent digestibility and ileal nitrogen losses in pigs. J. Anim. Sci. 72:2362-2368.

16. Schulze, H., P. van Leeuwen, M.W.A. Verstegen, J.W.O. van den Berg. 1995. Dietary level and source of neutral detergent fiber and ileal endogenous nitrogen flow in pigs. J. Anim. Sci. 73:441-448.
17. Lenis, N.P. and J.B. Schutte. 1990. Amino acid supply of piglets and grow-finish pigs in relation to nitrogen excretion. In: Manure issues: nutritional solutions for pigs and poultry (A.W. Jongbloed and J. Coppoolse, eds.). p. 79-89.
18. Baker, D.H. 1996. Advances in amino acid nutrition and metabolism of swine and poultry. In: Nutrient Management of Food Animals to Enhance and Protect the Environment (E.T. Kornegay, ed.). p. 41-53. Lewis Publishers, Boca Raton, Florida.
19. Reese, D., and R. Koelsch. 1999. Altering swine manure by diet modification. Nebraska Cooperative Extension Publication G99-1390-A. University of Nebraska, Lincoln.
20. Schutte, J.B., J. de Jong, and G.J.M. van Kempen. 1993. Dietary protein in relation to requirement and pollution in pigs during the body weight range of 20-40 kg. In: Nitrogen flow in pig production and environmental consequences (Verstegen, M.W.A., L.A. den Hartog, G.J.M. van Kempen, and J.H.M. Metz, eds.) p. 259-263. Pudoc Scientific Publishers, Wageningen.
21. Monge, H., P.H. Simmins, and J. Weigel. 1998. Reductions of the protein content of diets combined with different methionine:lysine ratios. Effects on nitrogen balance in lean-genotype grow-finish pigs. J. Rech. Porcine en France 29:293-298.
22. Hobbs, P.J., B.F. Pain, R.M. Kay, and P.A. Lee. 1996. Reduction of odorous compounds in fresh pig slurry by dietary control of crude protein. J. Sci. Food Agric. 71:508-514.
23. Schaefer, J. 1977. Sampling, characteristics and analysis of malodours. Agri. Environ. 3: 121-127.
24. van Kempen, T., and P. H. Simmins. 1997. Near infrared reflectance spectroscopy in precision feed formulation. J. Appl. Poultry Res. 6:471-477.
25. van Kempen, T., B. Park, M. Hannon, and P. Matzat. 1999. Proper weighing key in making a quality feed. Feedstuffs, 71:12-13.
26. Jongbloed, A.W., and N.P. Lenis. 1993. Excretion of nitrogen and some minerals by livestock. In: Nitrogen flow in pig production and environmental consequences (Verstegen, M.W.A., L.A. den Hartog, G.J.M. van Kempen, and J.H.M. Metz, eds.). p. 22-36. Pudoc Scientific Publishers, Wageningen.
27. van Heugten, E. and T. van Kempen. 2000. Understanding and applying nutrition concepts to reduce nutrient excretion in swine. North Carolina Cooperative Extension Service, Publication no. AG-608. p. 1-15.
28. Creech B.L., J.W. Spears, W.L. Flowers, G.M. Hill, K.E. Lloyd, T.A. Armstrong, and T.E. Engle. 2004. Effect of dietary trace mineral concentration and source (inorganic vs. chelated) on performance, mineral status, and fecal mineral excretion in pigs from weaning through finishing. J. Anim. Sci. 82:2140-2147.
29. van Heugten, E., P. R. O'Quinn, D. W. Funderburke, W. L. Flowers, and J. W. Spears. 2004. Growth performance, carcass characteristics, plasma minerals, and fecal mineral excretion in growing-finishing swine fed diets with levels of trace minerals lower than common industry levels. J. Swine Health and Prod. 12:237-241.
30. van der Peet-Schwering, C., P., N. Verdoes, and M. Voermans. 1997. Ammonia emission 10% reduced with phase feeding. Research Institute for Pig Husbandry, Rosmalen, the Netherlands.
31. Aarnink, A.J.A. P. Hoeksma, and E.N.J. van Ouwerkerk. 1993. Factors affecting ammonium concentrations in slurry from fattening pigs. In: Nitrogen flow in pig production and environmental consequences (Verstegen, M.W.A., L.A. den Hartog, G.J.M. van Kempen, and J.H.M. Metz, eds.). p. 413-420. Pudoc Scientific Publishers, Wageningen.
32. Aarnink, A.J.A., A.L. Sutton, T.T. Cahn, M.W.A. Verstegen, and D.J. Langhout. 1998. Dietary factors affecting ammonia and odour release from pig manure. In: Biotechnology in the feed industry. Proceedings of the Alltech's 14th annual symposium (Lyons, T.P., and K.A. Jacques, eds.). p. 45-59. Nottingham University Press, Nottingham, U.K.
33. Mroz, Z., A.W. Jongbloed, K. Vreman, T.T. Cahn, J. T.M. van Diepen, P.A., Kemme, J. Kogut, and A.J.A. Aarnink. 1996. The effect of different dietary cationanion supplies on excreta composition and nutrient balance in growing pigs. Institute of Animal Science and Health, Lelystad, The Netherlands, Report No. 96.028.
34. den Brok, G., C. van der Peet-Schwering, and M. Vrielink. 1997. Urine-pH, ammonia emission, and technical results of grow-finish pigs after addition to the feed of organic acids, specifically benzoic acid. Research Institute for Pig Husbandry, Rosmalen, the Netherlands.
35. Mackie, R.I., P.G. Stroot, and V.H. Varel. 1998. Biochemical identification and biological origin of key odor components in livestock waste. J. Anim. Sci. 76:1331-1342.
36. Shurson, J., M. Whitney, and R. Nicolai. 1999. Manipulating diets may reduce hydrogen sulfide emissions. Feedstuffs, 25 Jan.:12-17.
37. Brumm, M.C., J.M. Dahlquist, and J.M. Heemstra. 2000. Impact of feeders and drinker devices on pig performance, water use and manure volume. J. Swine Health Prod. 8:51-57.
38. den Brok, G., and J. van Cuyck. 1993. Manure production and water consumption: comparison between theory and practice. Research Institute for Pig Husbandry, Rosmalen, the Netherlands.