NUTRITIONAL STRATEGIES TO MINIMIZE NUTRIENT OUTPUT

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ABSTRACT

In many areas of the world the contribution of animal agriculture to environmental pollution has become a serious concern. Through science-based nutritional strategies, the mineral balance on pig farms can be substantially improved. Most of these strategies are quite simple to implement and can have a significant impact on profitability as well. The most promising and practical of these strategies focus on two main principles - minimizing input and maximizing the efficiency of utilization. Using phytase, replacing protein with synthetic amino acids, and by feeding more closely to the animal's requirements, nitrogen and phosphorus excretion in pig manure can be reduced by up to 50%. Application of nutritional strategies to reduce mineral excretion will increase the need for accurate evaluation of available nutrient content in pig feed ingredients, precise feed formulation and manufacturing.

INTRODUCTION

In areas with intensive pig production, the negative impact of pig production on the environment is one of the main factors that limits the expansion of the pork industry and affects the attitude of the general public towards animal production (e.g. Kornegay and Verstegen, 2001). In several countries legislation has been introduced, or recommendations have been made, to reduce or to minimize the contribution of animal agriculture to environmental pollution. These imposed regulations, or recommendations, generally increase production costs and have forced the agricultural industry to seek means to reduce the production of animal waste.

This paper discusses the general principles of nutrition as it relates to nutrient management and focuses on ways of manipulating the pig's diet and the feeding program to reduce the excretion of nutrients in pig manure. The nutrients of prime concern are copper (Cu), zinc (Zn), nitrogen (N) and phosphorus (P). Potassium (K) should be considered as well, as it affects the fertilizing value of manure.

COPPER AND ZINC

In general, Cu and Zn in pig diets are much higher than the minimum requirements for normal performance (i.e. 5-25 ppm Cu and 50-125 ppm Zn for the various classes of swine; National

Research Council, 1998). These minerals act as growth promotants when included at levels much higher than minimum requirements. In Canada, the federal Feeds Act limits the maximum level of Cu and Zn in the diet to 125 ppm and 500 ppm respectively, but in the US, much higher levels are common. In some countries, like the Netherlands, growth promoting levels of Cu and Zn are no longer allowed in finisher pig diets due to the impact on the environment. As long as minimum requirement levels of Cu and Zn are maintained, the excretion of these minerals in pig manure is not a concern; the focus then switches to N and P excretion.

MINERAL BALANCES

The efficiencies by which animals use nutrient intake for mineral retention in useable animal products are generally low. On swine farms, the efficiency of K retention is very low (3.6 to 10%) while the efficiency is somewhat higher for N and P retention (18 to 40%)(Table 1). Overall, approximately two-thirds of N and P intake is excreted in manure. Starter pigs are slightly more efficient while sows are less efficient. However, since grower-finisher pigs produce the majority of the manure on a typical farrow-to-finish operation, typical values for these operations would be similar to the values shown for grower-finisher pigs. This extremely low level of efficiency and between farm variability leaves room for decreasing mineral excretion by improving the efficiency of retention in the pig (de Lange, 2002).

Table 1. Typical mineral balances (kg/animal) on Dutch pig farms (Jongbloed, 1991).

	Nitrogen	Phosphorus	Potassium
	I. Growing pigs (25-106 kg live weight)		
Dietary levels (%)	16.7*	.52	1.22
Intake (kg/pig)	6.36	1.23	2.90
Excretion (kg/pig)	4.48	.83	2.73
Retention (kg/pig)	1.88	.40	.17
Efficiency of retention (%)	29.5	32.5	6.0
	II. Sows, including nursing piglets		
Dietary levels (%)	15.7*	.59	1.32
Intake (kg/sow/yr)	27.57	6.53	14.52
Excretion (kg/sow/yr)	22.50	5.5	14.0
Retention (kg/sow/yr)	5.07	1.03	.52
Efficiency of retention (%)	18.4	15.8	3.6
	III. Starter pigs (9-25 kg live weight)		
Dietary levels (%)	18.4*	.67	1.25
Intake (kg/pig)	.94	.21	.40
Excretion (kg/pig)	.56	.13	.36
Retention (kg/pig)	.38	.08	.04
Efficiency of retention (%)	40.5	39.4	10.0

*Crude protein (N x 6.25) rather than N levels.

Variation in the amount of minerals excreted with manure between farms can be attributed to various animal and feed factors. These include:

- feed usage and feed wastage
- the level and digestibility of amino acids and P in the various diets
- the minimum amounts of N and P required by the pig for basic body functions (maintenance requirements)
- the (marginal) inefficiency of utilizing amino acids and P that are supplied over maintenance but below maximum N and P retention in the pig's body
- the balance of amino acids supplied in the diet vs. the balance of amino acids required
- the rate of N and P retention in the pig's body

Given the large variation between farms and environmental pressures, the need to closely monitor N and P balances on individual pig units will increase. This can be best accomplished by closely monitoring the amount and composition of feeds, or feed ingredients, that are used and the number and weight of animals that are removed from the farm. In the Netherlands, such a mineral book-keeping system is obligatory for farms that have more than 2.5 large animal units (about 10 growing-finishing pig places) per hectare of land, and requires that feed companies provide statements regarding amounts of nutrients that are delivered to each farm. With this approach, the calculated nutrient balances are rather sensitive to initial and final nutrient inventories with feed and manure (MINAS, 2002).

In Ontario, this approach to calculating nutrient balances has been integrated into 2 computer programs used to accurately predict the excretion in manure of the minerals of concern (N, P, K) in environmental pollution (Birkett and de Lange, 1998; NMAN, 2003). In this approach, N, P and K excretion in pig manure is calculated from the difference between the amounts of N, P, and K that are fed to the animals (based on amounts of various feeds used and the N, P, and K content in the various feeds) and the amounts of N, P, and K removed from the farm in animals (based on the number of pigs in each category, live and dead, that are removed from the farm) (Birkett and de Lange, 1998). NMAN is a software tool developed by the Ontario Ministry of Agriculture and Food that assists farmers in predicting nutrient generation, based on manure analysis or database values, and determining land base requirements for agronomic use of nutrients (NMAN, 2003).

LOWERING NITROGEN AND PHOSPHORUS EXCRETION THROUGH NUTRITION

Over the last ten years some extensive reviews have been published in which various nutritional means to improve the efficiencies of N and P retention in pigs are addressed (eg. Verstegen et al., 1993; Lenis and Jongbloed, 1995; Coelho and Kornegay, 1996; National Research Council, 1998; Kornegay and Verstegen, 2001; van Kempen and van Heugten, 2001; Ferket et. al., 2002). In this paper, only the main and most relevant means to improve the efficiency of N and P retention will be discussed. Other means, including plant breeding (to manipulate feed ingredients from plant origin), feed ingredient selection, and use of enzymes other than phytases are discussed elsewhere (eg. Verstegen et. al., 1993; Lenis and Jongbloed, 1995; Coelho and Kornegay, 1996; National Research Council, 1998; Kornegay and Verstegen, 2001).

The three most expensive components of a swine ration are N (an important component of protein and amino acids), P and energy. Nitrogen and P are also the most important contributors to pollution from swine manure, so it is important to maximize the efficiency with which these nutrients are used. Excretion of N and P in swine manure can be substantially reduced by a number of strategies.

Improve Feed Efficiency

Improved productivity is the most obvious strategy for reducing nutrient excretion. In general, a better feed efficiency leads to a lower excretion of N and minerals. An improvement in feed conversion of 0.25 units would reduce N excretion by 5 to 10% (Coffey, 1996). Over the past 20 years, the feed efficiency of pigs growing from 25 kg to market weight has gradually decreased from approximately 4.0 to less than 2.85 in top-producing herds.

Reduce Feed and Water Wastage. Although often overlooked, a significant amount of feed nutrients may end up in manure simply because it was not consumed by the pig. Poor feeder design, improperly adjusted feeders, and feed form can contribute to a major feed wastage problem that directly impacts on nutrient output. Research in this area has estimated that feed wastage can range from 2-20%, with typical operations at 5-6% (Gonyou and Lou, 1998). In general, N and P in manure will increase by 1.5% for every 1% increase in feed waste (Ferket et. al., 2002). If there is a noticeable amount of feed on the floor, at least 10% is being wasted. To limit feed wastage producers can feed pelleted rations, pay close attention to feeder design, and adjust feeders properly. A good general guideline is to manage feeders so that only 50% of the bottom of the feeder is covered (van Kempen and van Heugten, 2001).

Water wastage does not affect the amount of nutrients excreted, but it will adversely affect manure processing and increase manure volume and disposal costs (Ferket et. al., 2002). The new generations of nipple drinkers have been designed to reduce water use compared to conventional nipple drinkers, which tend to be favourite play toys for pigs. Bowl or cup systems, although difficult to keep clean, also reduce water wastage. Wet-dry feeders and liquid feeding systems offer options for greater control over water use and the impact of water wastage on manure volumes.

Improve Feed Digestibility. Proper processing of feeds represents a very practical means to positively impact nutrient excretion through improvements in feed digestibility. Pelleting of feeds has been estimated to improve feed efficiency, through increased energy and protein digestibility, by 6.6% and subsequently reduce N excretion by 5% (Wondra et. al., 1995). Particle size is an area where producers can significantly improve feed efficiency. Research at Kansas State University has indicated that, for corn-based diets ranging in particle size from 1200 - 400 microns, there is a 1 - 1.5% improvement in feed efficiency for every 100 micron reduction in average particle size. Kansas State University recommends an optimum particle size for pigs of 700 - 800 microns. Other means to improve diet nutrient digestibility include the use of ingredients with highly digestible nutrients and the use of enzymes, especially phytase. These two means are presented further in this document.

It should be noted that improvements in digestibility will only improve nutrient utilization if total dietary nutrient intake is reduced. For example, recent research at Prairie Swine Centre (2002) has indicated that reducing particle size from 900 to 600 microns was effective in reducing fecal N by 11%, but not total N excretion. This is likely because feed intake was not reduced with decreasing particle size and excess digestible protein intake was broken down after absorption and excreted in urine.

Improve Animal Productivity. Pigs with improved lean growth potentials can have a better feed efficiency as a result of reduced fat tissue growth and higher carcass lean yield as compared to conventional pigs (Jongbloed and Henkens, 1996). Feed additives that promote lean tissue growth may also reduce excretion of N and P as a result of a better feed conversion compared to non-supplemented feeds. In addition, improvement in the herd health status, or in the thermal environment to which pigs are exposed, will lead to improvements in feed efficiency and thus reductions in mineral excretion. Keller (1980) estimated that converting to a specific-pathogen-free herd health status can improve feed efficiency by as much as 10% and, as a result, decrease N excretion by 10%.

Phytase

The most important anti-nutritional factor in swine nutrition, as it relates to nutrient management, is phytate. The major ingredients in pig diets are seeds (cereal grains) or products from seeds (oilseed meal and grain byproducts). However, 60-80% of the P in these feedstuffs is present in the form of phytate, a compound that pigs do not use well. Bioavailability estimates of P in corn and soybean meal for pigs range from 10-30% (Kornegay, 1996). This low availability of phytate P poses two problems for producers - the need to add inorganic P supplements to diets and the excretion of large amounts of P in the manure.

Phytate P must be hydrolyzed by an enzyme, phytase, into inorganic P before it is available to pigs. Four sources of phytases have the potential to degrade phytate within the digestive tract of pigs - intestinal phytase in digestive secretions, endogenous phytase present in some feed ingredients, phytase originating from resident bacteria, and phytase produced by exogenous microorganisms. Unfortunately, all of these potential sources have proven to have negligible phytase activity for improving phytate availability in non-ruminant animals fed corn and soybean meal based diets (Kornegay, 1996).

Phytate also impairs the bioavailability of minerals other than P. Minerals that may be bound by phytate include Zn, Cu, manganese (Mn), iron (Fe), magnesium (Mg), calcium (Ca) and chromium (Cr). Hydrolysis by phytase should release the minerals that are bound, allowing for improved absorption of Ca, Mg, Zn and Fe in pigs (Kornegay, 1996).

Research has proven that phytase added to the diet can improve P digestibility. As a result, the total P levels in the diet should be reduced to improve the efficiency of retention and reduce excretion of P into the environment by 25 - 50% (Table 2). In addition, feeds supplemented with phytase for grower-finisher pigs and for pregnant sows may need little or no supplementary feed phosphate. Currently, the addition of phytase does not appear to add more cost to the diet because it is offset by the savings associated with reducing P and Ca in the diet. Despite it being cost neutral, phytase use in Ontario remains at 20-30% compared to 70% in Quebec (de Lange et. al., 2003).

Table 2. Estimated excretion of nutrients by pigs without and with phytase (modified from Kornegay, 1998).

Assumptions for 113 kg Market Hog (birth to 113 kg):
- 306 kg of feed/pig
- 88% DM, 16.5% CP (2.64% N), 0.55% total P in diet
- 85% DM digestibility, 38% N retention, 38% P retention

Excretion per Market Hog:
- 40 kg DM [306 x 0.88 x (1 – 0.85 = 0.15)]
- 5 kg N [306 x 0.0264 x (1 – 0.38 = 0.62)]
- 1 kg P [306 x 0.0055 x (1 – 0.38 = 0.62)]

Excretion for Hogs Marketed in Ontario (5.33 million in 2003):
- 1.63 million metric tonnes of feed fed, 213,200 metric tonnes of DM excreted
- 26,650 metric tonnes N and 5330 metric tonnes P excreted

Phytase Feeding and Reduction in P Fed:
- A 0.1% unit reduction of P fed and the feeding of 500 units/kg of microbial phytase would result in 1630 metric tonnes less P excreted (1.63 million metric tonnes x 0.1%) or a 31% reduction in P excreted

Various points should be considered when including phytases in pig diets (Jongbloed and Kemme, 1990; Simons et. al., 1990; Jongbloed et. al., 1993; Coelho and Kornegay, 1996; Kornegay and Verstegen, 2001):

- Different commercial products differ in the content of active phytase. Phytase units (PTU) may be used to compare different products using a standardized test.
- The efficacy of phytases is not the same for all feed ingredients and diets. This likely reflects differences in the location within the seed where phytate is deposited, eg. in the germ in corn and the aleurone layer in wheat (O'Dell et. al. 1972).
- Not all phytases are stable when exposed to heat. During pelleting the temperature of the feed should not exceed 70-75^{o}C when uncoated phytases are included. Phytase activity should be checked in the complete, processed feed. Phytases with higher heat stability are now commercially available.
- Phytases not only increase the digestibility of P; they also increase the digestibility of Ca and other trace minerals that are tied to the phytate complex (Cu, Zn, etc.). Phytase can

improve feed utilization (by 1-2%) in starter and grower pigs by making other nutrients more available as well (eg. Mroz et. al., 1994). This results in additional "value" of added phytase.

- When determining the value of phytase, the effects of reducing the P and Ca levels in the diet should be considered. In particular, in high energy diets in which (expensive) fat is used, a reduction in mineral levels will be associated with a reduced need to use fat as there is more "space" in the feed formula. This results in reduction of ingredient costs.
- The marginal improvement in P digestibility declines with increasing levels of phytase (Kornegay and Verstegen, 2001). For example, in a low P containing diet (0.381% total P, the response to phytase is larger at low levels (less than 200 PTU/kg of feed: .021% extra dig. P/ kg of feed per 100 additional PTU) than at intermediate levels (200 to 600 PTU/kg of feed: .010% extra dig. P / kg of feed per 100 additional PTU). At high levels, improvements in P digestibility are further reduced (more than 600 PTU/kg of feed: .0035% extra dig. P/ kg of feed per 100 additional PTU). Effectively and in corn and soybean meal based diets for grower-finisher pigs, 500 PTU units can replace 0.1 percentage units of total dietary P (Kornegay and Verstegen, 2001). It should be noted that there is still some debate about the effect of pig age/weight on the response to phytase (it may be better than the indicated values at higher body weights).
- The utilization of P is affected by the Ca to P ratio in the diet; these should be maintained low (1–1.25:1 total or 2-3:1 available; National Research Council, 1998).

Formulate Based on Nutrient Availability

The bioavailability of N and P varies considerably from one feed ingredient to another (Table 3). The major reason for the inefficiency of P utilization in monogastrics is the poor digestibility/availability of P that is present in plant products, largely because much of the P in plants is in the phytate form. In contrast, the availability of P in animal and inorganic sources is much higher. For this simple reason, pig diets should be formulated on available/digestible, rather than total, nutrient basis.

Variation in nutritional value of feed ingredients is an economic and environmental concern. Without complete and timely ingredient analysis, there is a tendency for manufacturers to over-formulate rations resulting in higher ration costs and increased potential for nutrient losses. The use of book values (like those available from the National Research Council, 1998) for feed formulation will not be sufficient in the future. As we endeavor to feed pigs more closely to their requirements, it will become increasing important that techniques are available to determine both nutrient levels and availabilities. The use of near infrared reflectance (NIR) technology or other rapid nutrient analysis methods prior to mixing feed could allow for "real-time" feed formulation and significant reductions in safety margins of nutrients (Ferket et. al., 2002).

Assessing Phosphorus Availability. For determining the availability of P in ingredients for swine, two different approaches have been used. One approach, used in the United States is based on a slope-ratio assay in which bone characteristics are related to the inclusion level of the test source of P in the diet (Cromwell, 1993; National Research Council, 1998). Values are compared to a standard source of P, monosodium phosphate. A second approach, used in

The Netherlands and France, is to determine apparent faecal P digestibility in P sources at low levels of P intake (eg. Jongbloed, 1987; CVB, 1998; Jongbloed et. al., 1999). There is some general agreement for most feed ingredients between the two methods. However, differences are apparent for some ingredients, such as canola meal, dehulled soybean meal and dicalcium phosphate and raises concerns about the adequacy of these approaches to estimate P availability and within ingredient variability in P availability. In The Netherlands, the use of digestibility values has lead to an increase in the use of monocalcium phosphate, rather than dicalcium phosphate, as the mineral source of choice in pig diets. At the University of Guelph, Dr. Fan is leading a research project to determine true phosphorus digestibility in pig feed ingredients (Fan et. al., 2001), which is a further refinement of the apparent digestibility assay used in The Netherlands and France.

Table 3. Bioavailability of nitrogen and phosphorus in feed ingredients for pigs (National Research Council, 1998).

Feedstuff	Bioavailability		Feedstuff	Bioavailability	
	P* (%)	N** (%)		P* (%)	N** (%)
Cereal Grains			High Protein Meals - Plant		
Corn	14	78	Canola meal	21	78
Oats	22	76	Soybean meal, dehulled	23	90
Barley	30	79	Soybean meal , 44% protein	31	89
Triticale	46	81			
Wheat	50	81	High Protein Meals - Animal		
			Feather meal	31	67
Grain By-products			Meat and bone meal	90	80
Oat groats	13	79	Dried skim milk	91	93
Corn gluten meal	15	80	Blood meal	92	94
Rice bran	25	78	Fish meal	94	95
Wheat bran	29	71	Dried whey	97	87
Brewers grains	34	82			
Wheat middlings	41	89	Inorganic Phosphates		
Corn gluten feed	59	66	Steamed bone meal	85	-
Distillers grains	77	75	Defluorinated phosphate	90	-
			Monocalcium phosphate	100	-
Miscellaneous			Dicalcium phosphate	100	-
Alfalfa meal	100	56			

* relative to the availability of P in monosodium/monocalcium phosphate which equal 100
**true ileal digestibility of lysine

Feed ingredients vary considerably in their nutrient content across ingredients and also within a single feed ingredient. When researchers at the University of Guelph analyzed the P and phytate levels in Ontario corn and soybeans they found large differences depending on variety, location, and growing conditions (Leech and de Lange, 2002a,b). In corn, total P content ranged from 0.22% to 0.42% while phytate levels varied from 48% to 90% of total P. In soybeans, total P levels varied from 0.36% to 0.84% with the percent as phytate from 43%

to 71%. Unfortunately, at the present time, there is no quick commercially available method to routinely determine phytate levels.

Assessing Amino Acid Availability. As we feed pigs more closely to their requirements, it will become increasingly important that the amino acid availabilities in feed ingredients are accurately determined. This applies in particular to lysine, which is generally the first limiting amino acid in pig diets. It is generally accepted that the ileal amino acid digestibility assay provides reasonable estimates of amino acid availability in the various ingredients (Table 3). However, in heat-treated protein sources, or in ingredients containing large quantities of anti-nutritional factors, the ileal digestibility assay may over-estimate amino acid availability. Novel techniques are being developed to routinely estimate amino acid availability in feed ingredients (Moughan and Rutherfurd, 1996).

Match Supply of Available Nutrients to Requirements

The key to minimizing nutrient output is by feeding animals according to their nutrient requirements. Over- or underfeeding nutrients relative to the animal's requirement will increase output since animals will simply excrete all of the nutrients they are unable to use for maintenance and growth. Accurate estimates of nutrient requirements are essential to optimize the production system but they are a moving target, depending on factors such as energy density of the diet, stage of development, genetic potential, sex, environmental temperature, and health status. Since nutrient requirements and the optimum dietary nutrient levels differ between individual pig units, the main determinants of nutrient requirements may be monitored on individual pig units. In grower-finisher pigs, estimates of feed intake and lean tissue growth will provide good information for nutritionists to establish target diet nutrient levels (de Lange et. al., 2001).

Phase Feeding. As the liveweight of a pig increases from 30 to 110 kg, the optimum concentration of amino acids and P in the feed decreases. So, the introduction of one or more additional feed(s) for grower-finisher pigs will help balance amino acids and digestible P in the diet to the requirements of the animal so less N and P is excreted (Figure 1). When diets are precisely formulated to meet the protein and amino acid requirements of pigs, N excretion is reduced due to decreased dietary excess and improved utilization of nutrients. Calculations show that by changing from one feed system that is common in Ontario to a 2-phase system, the N needs would be met more precisely resulting in a reduction in N in manure of 12% (Table 4). Going from a 1-phase to a 3-phase feeding program should reduce N excretion by about 17.5% (van Kempen and van Heugten, 2001). Clearly, the incremental benefit of implementing one additional diet in a phase feeding program is smaller as the number of diets in the phase feeding program is increased.

A slightly larger reduction in N and P excretion can be achieved for growing pigs by mixing a feed rich in protein and minerals with a feed that has a low concentration of protein and minerals in a changing ratio during the growing period. This mixing system, referred to as multiphase feeding, works with a computerized mechanical feeding system. A feeding strategy is developed once a good fit of energy, protein, and mineral supply has been established based on pig potential, stage of production, production objective and environmental constraints (Jongbloed and Henkens, 1996).

Figure 1. Effect of number of feed phases on nutrient excess relative to nutrient requirement.

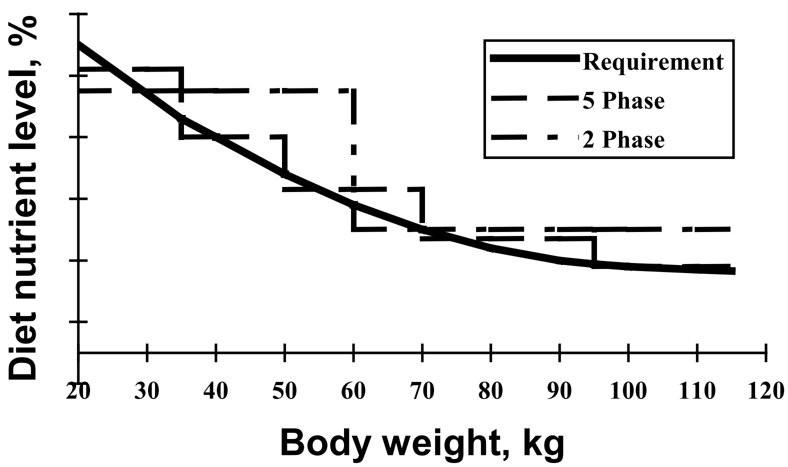

Table 4. The effect of phase feeding on nitrogen excretion in grower-finisher pigs.

Item	One Feed	--------- Two Feeds ---------		
		Grower	Finisher	Overall
Protein (%)	16	16.5	14	14.88
Feed:gain	2.85			2.82
Feed intake (kg)	257	89	165	254
N intake (kg)	6.57	2.35	3.70	6.05
N retention (kg)	2.3			2.3
N excreted (kg)	4.27			3.75
N excreted (%)	65			62
% improvement				12

Split-Sex Feeding. Feeding barrows and gilts separately can also decrease excretion of N and P. It is well known that barrows eat more feed, grow faster, are less feed efficient and yield lower carcass lean than gilts. Although there is little difference between barrows and gilts up to 25 kg, differences in feed intake and growth rate may be as high as 15% during the finisher phase. Because they eat less feed and have a higher lean growth rate, gilts require higher levels of amino acids and other nutrients than barrows. Different diets can be fed to more closely match the nutrient requirements of the separate sexes while limiting excesses and reducing excretion.

Replace Protein with Synthetic Amino Acids

Protein is an expensive nutrient in pig diets, so maximizing the efficiency of protein and amino acid utilization is important. Diets containing amino acids at minimum requirement (for maximum lean growth) with minimal excesses is critical. An experiment using chemically defined diets containing amino acids as a sole source of dietary N, showed that, with a near perfect amino acid balance, a 15 kg pig is capable of converting 87% of its absorbed N above maintenance to body protein. This does not mean that each of the 23 amino acids found in dietary protein are used at 87% efficiency for protein (some are used more efficiently, others less). Ideal ratios of essential amino acids to lysine have been proposed, suggesting an "ideal protein" that corresponds to the pig's requirement (Table 5).

Feed ingredients are combined to meet the pig's requirements for the most limiting amino acid. As a result, the protein content of the diet is higher than required because of the presence of excess amino acids. For grower-finisher pigs, the greatest improvements in the efficiency of N utilization can be achieved from improving the dietary amino acid balance, so that the diet more closely reflects the true balance in which amino acids are required. Through manipulation of the dietary amino acid balance, N excretion in manure can be substantially reduced, by 35% in grower pigs and 20% in finisher pigs, without affecting animal performance (Tuitoek et. al. 1997). In a simple example, N excretion can be decreased by approximately 15% when a 16% protein grower diet is replaced by a 14% protein finisher diet at 60 kg.

Table 5. Ideal amino acids ratios for pigs in four weight ranges, expressed on a true ileal digestible basis (National Research Council, 1998).

	Ideal Ratios (% of lysine)			
Amino Acid	10-20 kg	20-50 kg	50-80 kg	80-120 kg
Lysine	100	100	100	100
Arginine	42	40	36	31
Histidine	32	31	32	31
Isoleucine	54	54	56	56
Leucine	101	100	102	98
Methionine	27	27	27	27
Methionine + Cystine	57	57	59	60
Phenylalanine	60	59	61	60
Phenylalanine + Tyrosine	94	94	95	94
Threonine	62	63	65	65
Tryptophan	18	18	18	19
Valine	68	67	68	67

Synthetic amino acids are commonly added to swine diets. L-Lysine-HCL is the most commonly used, and DL-methionine is used in some diets. Recently, synthetic L-threonine and L-tryptophan have become commercially available. The ability of the swine industry to efficiently use competitively priced synthetic amino acids is limited by our knowledge of amino acid requirements of pigs and of biological availability of amino acids in feed ingredients (Coffey, 1996). The order in which amino acids become limiting will vary with pig body weight, body protein gain and feeding level. With the current cost of synthetic amino acids, it does not make sense to include synthetic amino acids other than lysine in grower pig diets but this will change as the availability and price of other amino acids improves (de Lange, 2002).

CONCLUSIONS

In many areas of the world the contribution of animal agriculture to environmental pollution has become a serious concern. In some countries this has lead to the introduction of legislation to reduce mineral excretion by farm animals. Through science-based nutritional strategies, the mineral balance on pig farms can be substantially improved. Most of these strategies are quite simple to implement and can have a significant impact on nutrient output (Table 6) and the operation's profitability. The most promising and practical of these strategies focus on two main principles - minimizing input and maximizing the efficiency of utilization. Using phytase, replacing protein with synthetic amino acids, and by feeding more closely to the animal's requirements, N and P excretion in pig manure can be reduced by up to 50%. Application of nutritional strategies to reduce mineral excretion will increase the need for precise feed ingredient evaluation, feed formulation, manufacturing, and delivery. Reducing water wastage from drinkers can also have an impact on manure volumes.

Table 6. Potential impact of nutritional strategies on excretion of nitrogen and phosphorus (van Heugten and van Kempen, 2001; Ferket et. al., 2002).

Strategy Used		Reduction in Nutrient Excretion
Improve feed efficiency	➜	3% for every 0.1 unit in improvement
Minimize feed wastage	➜	1.5% for all nutrients for every 1% reduction
Match nutrient requirements	➜	6-15% for N and P
Phase feeding	➜	5-10% for N and P
Split-sex feeding	➜	5-8% for N
Phytase	➜	2-5% for N; 20-50% for P
Formulate on nutrient availability	➜	10% for N and P
Replace protein with amino acids	➜	9% for N for every 1% reduction in crude protein
Highly digestible feed ingredients	➜	5% for N and P
Pellet the ration	➜	5% for N and P
700-1000 micron particle size	➜	5% for N and P
Enzymes: cellulases, xylanases, etc.	➜	5% for N and P for appropriate diet
Growth promoting feed additives	➜	5% for all nutrients
Low-phytate corn	➜	25-50% for P

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