THE IMPACT OF NUTRITION ON REDUCING THE IMPACT OF THE SWINE INDUSTRY ON THE ENVIRONMENT

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Introduction

Careful nutrient management planning is needed with increased intensity of the pork industry and with increased public concerns regarding nutrient excretion or odour emissions. Over-supplementation of diets with nutrients to ensure maximum pig performance resulted in excessive amounts of nutrients excreted in faeces and urine (Baker and Zublena 1995).

Successful nutrient management is key for sustainable pork production. The two principal nutrients of concern are nitrogen and phosphorus. Nitrogen is of concern because of its impact on the inside and also outside barn environment. Swine production has been recognized as a major source of ammonia, which is a noxious gas for humans and animals and contributes to bad odour and acidification of the environment. The main component of ammonia emission originates from urea in urine. Faecal nitrogen is less volatile than urinary nitrogen, because faecal nitrogen is bound chemically within proteins or other compounds. Phosphorus is excreted in urine and faeces, and could have a major impact on the environment and the economy if not managed properly (Cromwell et al. 1993; Liu et al. 1998; NRC 1998).

In the presentation, three projects relating diet manipulation to nutrient management will be discussed. Project 1 investigated changes in diet formulation such as dietary protein and fermentable fibre as means to alter nitrogen excretion patterns (Zervas and Zijlstra 2002ab). Project 2 investigated two nutritional strategies related to feed processing, dietary particle size reduction and enzyme supplementation, as a means for reducing nitrogen and phosphorus excretion from grower pigs (Oryschak et al. 2002). Project 3 investigated phosphorus requirements of grower pigs, because a better understanding of phosphorus requirements may enable diet formulation closer to pig requirements to reduce phosphorus excretion (Ekpe et al. 2002). Together, these projects give some examples for underlying mechanisms to reduce nitrogen and phosphorus excretion while maintaining pig performance.

Dietary protein and fermentable fibre

Reduced dietary protein while balancing for AA reduces urinary and total nitrogen excretion (Dourmad et al., 1993; Canh et al., 1998). Fibre may shift nitrogen excretion from urea in urine to bacterial protein in feces (Morgan and Whittemore, 1988).

To test these hypotheses, project 1 focussed on dietary protein and fermentable fibre (Zervas and Zijlstra 2002b). Two levels of crude protein (high, 18.5% and low, 15.6%)

and three sources of fibre [control, soybean hulls (15%), and sugar beet pulp (20%)] were tested in a 2 x 3 factorial arrangement. Diets (wheat, barley, soybean meal and corn starch) were formulated to 3.3 Mcal DE/kg and 2.4 g dLys/Mcal, supplemented with crystalline lysine, methionine, tryptophan, threonine, isoleucine, or valine to meet an ideal digestible amino acid profile. In other words, protein content of the low-protein diet was 3% lower than the high-protein diet, yet digestible amino acid balance was maintained.

Pigs (30 ± 3 kg) were housed in confinement-type metabolism crates for 26 d. Pigs had free access to feed from d 18 until the end of the experiment. Feces and urine were collected from day 23 to 26.

Nitrogen excretion patterns can be greatly altered using dietary manipulation. For example using reduced dietary protein content, urinary nitrogen excretion was 26% lower for low protein compared to high protein diets (Figure 1). Using fermentable fibre, fecal nitrogen increased 14% for soyhulls and 41% for sugarbeet pulp compared to control diet (Figure 2). Urinary nitrogen decreased 37% for soyhulls and sugarbeet pulp compared to control diets. Retention of nitrogen decreased 15% for soyhulls and 9% for sugarbeet pulp compared to control. Expressed as a percentage of nitrogen intake, fecal nitrogen excretion was increased 6% for soyhulls and 9% for sugarbeet pulp compared to control (Figure 2). Percentage urinary nitrogen excretion was reduced 8% for soyhulls and 10% for sugarbeet pulp compared to control.

Voluntary feed intake and body weight gain and feed efficiency were not affected by dietary treatments, suggesting that these dietary manipulation should work in a commercial setting, which was conformed in follow-up experiments (Payeur et al. 2002).

These results suggest that reduction of protein content is an effective way to reduce nitrogen excretion, especially urinary nitrogen. Use of fibre sources high in fermentable carbohydrates can shift nitrogen excretion from urine (urea nitrogen) to feces (protein-bound nitrogen), thereby reducing chances of ammonia emission (Payeur et al. 2002). Although ADG and feed efficiency were not affected by reducing dietary protein, further research is required to ensure that nitrogen retention or protein deposition is maintained.

Reducing dietary protein content will reduce urinary nitrogen and total nitrogen excretion in grower pigs. A reduction of total nitrogen excretion may reduce the land base required for sustainable manure application, if other nutrients are not becoming a limiting factor. The reduction of urinary nitrogen may reduce ammonia emission.

Feed enzymes and particle size

Nutrient digestibility is an important factor affecting overall efficiency of nitrogen and phosphorus utilization in pigs. Fineness of grind of dietary ingredients affects nutrient digestibility; thus, reducing particle size has been used to increase nutrient digestibility in pig diets (Wondra et al. 1995).

Progress in enzyme technology has produced supplemental enzyme cocktails that may assist pigs and poultry to digest less-digestible fractions in the diet (Bedford and Schulze 1998), thereby increasing nutrient digestibility and lowering feed costs. For example, phytase has consistently increased digestibility of phytate-phosphorus of ingredients fed to pigs (Jongbloed et al. 1992). Phytate is a complex molecule that binds phosphorus and other minerals. Enzymes that hydrolyse non-starch polysaccharides (NSP) in cereal grains (e.g., β-glucanase and xylanase) have been investigated but did not improve nutrient digestibility consistently across studies (Bedford and Schulze 1998).

Limited research has been conducted to study the effects of reducing particle size in combination with supplementation of either phytase or carbohydrase on nutrient digestibility and nitrogen and phosphorus excretion patterns in grower pigs.

To test the hypotheses, project 2 focussed on feed enzymes and particle size (Oryschak et al. 2002, Oryschak and Zijlstra 2002). Three particle sizes (400, fine; 700, medium; 850 μm, coarse) were compared within four enzyme treatments (control, CON; carbohydrase [β-glucanase + xylanase], CHO; phytase, PHY; PHY + CHO) in a 3 x 2 x 2 factorial arrangement for a total of 12 treatments. Diets were based on barley (70%) and peas (25%), and were formulated to limit in available phosphorus (0.12%), DE (3250 kcal/kg), and amino acids (1.6 g digestible lysine/Mcal DE). The diets were based on barley and field peas due to their low availability of phosphorus and therefore an expected positive effect of phytase on phosphorus digestibility.

Sixty barrows (25.3 ± 1.4 kg) were housed individually in metabolism pens to obtain five observations per treatment. Pigs were fed at 3 times maintenance DE.

Particle size. Fine particle size reduced fecal nitrogen excretion by 15 and 18% compared to the medium and coarse particle size diets, respectively. Urinary nitrogen excretion increased by 13 and 15% with medium and fine particle size, respectively, compared to coarse particle size diets (Figure 3). Fine particle size diets reduced total nitrogen excretion by 7 and 4% compared to medium and coarse particle size diets, respectively. Together, results indicate that finer grinding will improve nitrogen digestibility, but that only part of the increase in nitrogen absorbed is indeed retained. These results suggest that, most likely, the additional digested amino acids following finer grinding were not balanced to support protein deposition. The excess absorbed amino acids were catabolized and their nitrogen was excreted in the urine.

Fine particle size reduced fecal and total phosphorus excretion by 12% compared to medium particle size (Figure 4). Reducing dietary particle size can thus improve P digestibility, but probably only for the P not bound to phytate, although grinding may also disrupt the phytate molecule. Particle size reduction will increase nutrient digestibility by increasing the relative surface area of dietary particles exposed to enzymatic digestion in the gastrointestinal tract, thereby increasing nutrient digestion and absorption (Goodband et al. 1996).

Feed enzymes. Diets with phytase resulted in 4% less total nitrogen excretion than diets without, while diets with carbohydrase lowered fecal nitrogen excretion by 5% compared to those without (Figure 4). Phytase supplementation resulted in a 28% reduction in fecal and total nitrogen excretion compared to those without phytase. Urinary phosphorus excretion was insignificant compared to the amount excreted in the feces due to a limited supply of dietary phosphorus. Based on the low available P and expected low intrinsic phytase content in experimental diets in the present study, phytase was expected to improve P digestibility.

In summary, phytase and particle size reduction are effective strategies to reduce nitrogen and phosphorus excretion from grower pigs. Improvements in phosphorus digestibility by phytase were independent of dietary particle size. In contrast, effectiveness of carbohydrase appeared highest with coarse dietary particles, indicating that dietary particle size should be considered before carbohydrase application. Combined supplementation of carbohydrase and phytase may synergistically improve nitrogen digestibility.

Phosphorus requirements

The success of management strategies for reducing phosphorus excretion is dependent on an accurate estimate of the phosphorus requirement for a given level of pig performance and on the accuracy of compositional information on feed ingredients. Recently, supplemental phytase in swine diets has improved phosphorus digestibility and management (Cromwell et al. 1993). Beneficial effects of phytase may be enhanced with accurate phosphorus requirements for swine and accurate digestible phosphorus data for feed ingredients. Defining phosphorus requirements as digestible phosphorus instead of total phosphorus may enable diet formulation closer to actual pig requirements, a strategy that may have two benefits. First, phosphorus excretion in manure will be reduced. Second, the cost of excess dietary phosphorus will be eliminated thereby increasing net income of pork producers, because phosphorus is the third most expensive nutrient after energy and protein (NRC 1998).

The phosphorus requirements were defined based on (among others) phosphorus excretion patterns in project 3 (Ekpe et al. 2002). The assumption was that excess digested and absorbed phosphorus will be excreted in the urine.

Performance and metabolism studies were conducted to determine phosphorus requirements of grower pigs, using 200 pigs (23 ± 0.9 kg) and 20 barrows (54 ± 3.1 kg), respectively. Five levels of total phosphorus (0.42, 0.51, 0.55, 0.65, and 0.72%) were used in these studies. Experimental diets contained corn, barley, soybean meal and canola oil, and were formulated to 3.35 Mcal DE/kg and 0.80% digestible lysine.

Increasing digestible phosphorus quadratically increased ADG, feed intake, and feed efficiency (data not shown). In barrows, increasing digestible phosphorus intake increased quadratically phosphorus in plasma and urine (Figure 5), and linearly phosphorus in faeces, suggesting that phosphorus excretion depends in part on excess phosphorus intake. Using regression analysis, digestible phosphorus requirements were

6.67 g/d with plasma phosphorus and 4.01 g/d with urinary phosphorus, whereas feces phosphorus could not be used to determine phosphorus requirements. Excess digested and absorbed phosphorus will indeed be excreted in the urine. Feeding phosphorus closer to pig requirements will reduce phosphorus excretion and feed costs.

Increasing digestible phosphorus intake increased ADG, ADFI, and feed efficiency, but also increased phosphorus excretion in both urine and faeces. Reducing digestible phosphorus intake to the phosphorus requirement will be effective in reducing phosphorus excretion in manure. The strategy further eliminates the cost of excess phosphorus added to feeds, and may thereby increase net income. However, a successful management strategy for reducing phosphorus excretion is dependent on accurate estimates of phosphorus requirements for pigs to enable diet formulation closer to requirements. Using digestible phosphorus, instead of total phosphorus, as a criterion for estimating the nutritive value of phosphorus in diet formulation will reduce phosphorus excretion per pig.

Summary

Nutrient management is becoming increasingly important for sustainability of the swine industry. Diet manipulation to reduce nitrogen and phosphorus content of swine will thus be discussed. For example, effects of dietary particle size, dietary supplemental enzymes, dietary protein and fermentable fibre, and dietary phosphorus content on nitrogen or phosphorus content of feces and urine were determined in performance or metabolism studies. Together, results indicate that nitrogen and phosphorus excretion patterns can indeed be altered by diet manipulation.

Conclusions and implications

A reduction of dietary protein content while balancing for digestible amino acids will especially reduce nitrogen excretion in urine. With dietary fermentable fibre, part of urinary nitrogen excretion can be shifted toward nitrogen excretion in feces, and thus reduces volatile nitrogen that contributes to bad air quality.

Reducing particle size below 700 μm proved effective in altering nitrogen excretion patterns, while phytase proved very effective in improving digestibility of dietary phosphorus. The addition of carbohydrase showed little evidence of reducing total nitrogen or phosphorus excretion.

Reducing the excess amount of phosphorus in feeds is effective in reducing phosphorus in manure. The success of the management strategy for reducing phosphorus excretion is dependent on an accurate estimate of phosphorus requirements for pigs. A better understanding of the phosphorus requirements may enable diet formulation closer to the pig requirements to reduce the amount of phosphorus in manure. An improvement in phosphorus utilization is economically beneficial to pork producers, and is also important for sustainable swine production.

The reduction in excess nutrients and odour emissions while sustaining high levels of pork production is critical for long-term survival of a globally competitive pork industry.

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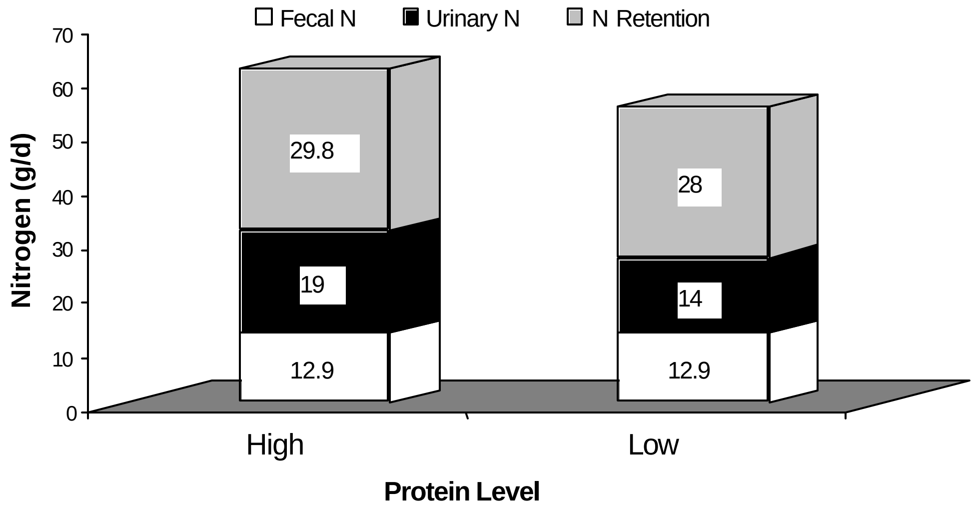

Figure 1. Effect of dietary protein level on fecal and urinary nitrogen excretion and nitrogen retention (in g/d; Project 1; Zervas and Zijlstra 2002b).

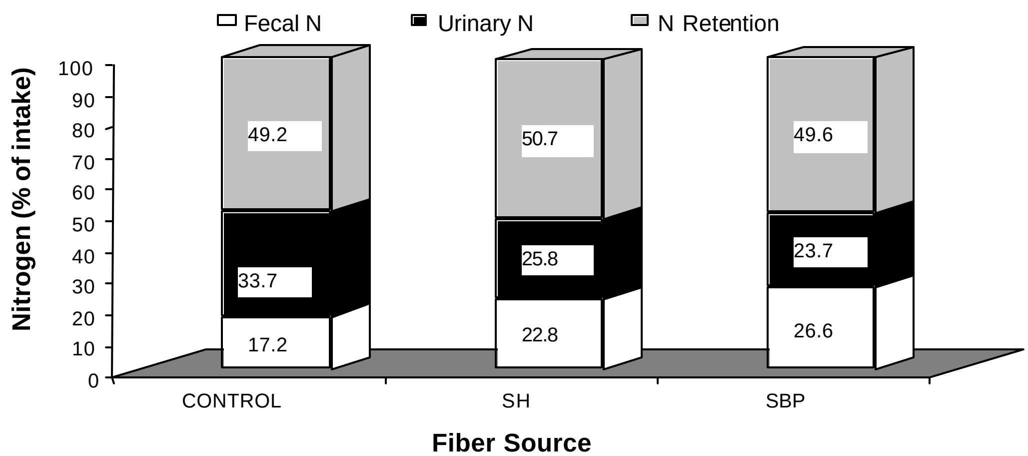

Figure 2. Effect of dietary fibre source (SH is soyhulls, SBP is sugarbeet pulp) on fecal and urinary nitrogen excretion and nitrogen retention (as % of nitrogen intake; Project 1; Zervas and Zijlstra 2002b).

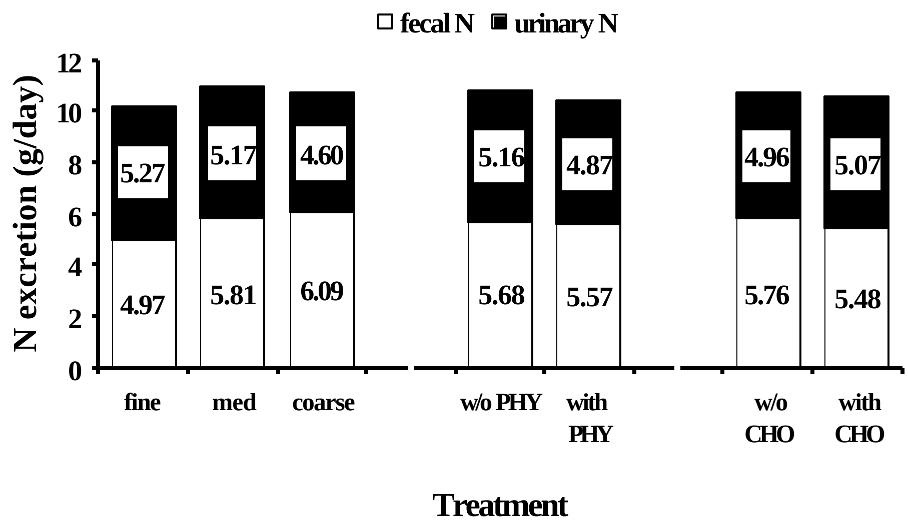

Figure 3. Total nitrogen excretion (g/day) partitioned by excretory route (Project 2; Oryschak et al. 2002). Treatments include: diet particle size (fine, med(ium), and coarse), dietary phytase (PHY) and dietary carbohydrase (CHO).

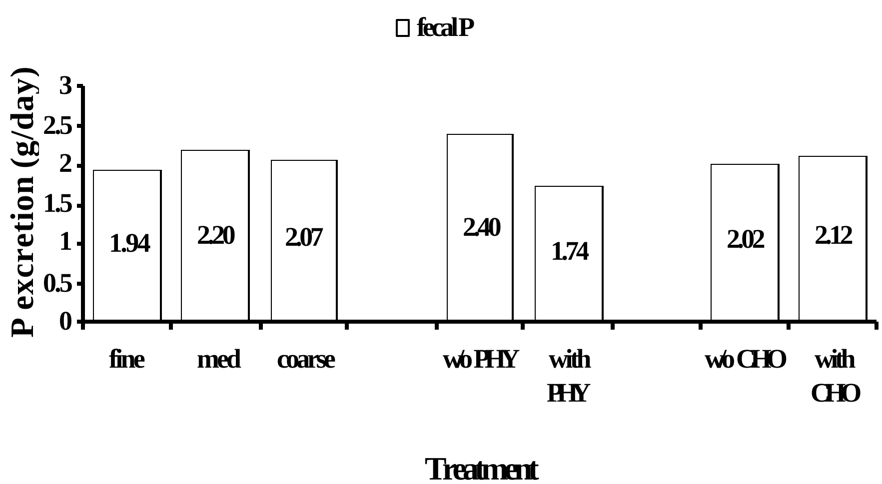

Figure 4. Fecal phosphorus excretion (g/d) for grower pigs fed a barley and field pea diet (Project 2; Oryschak et al. 2002). Treatments include: diet particle size (fine, med(ium), and coarse), dietary phytase (PHY) and dietary carbohydrase (CHO).

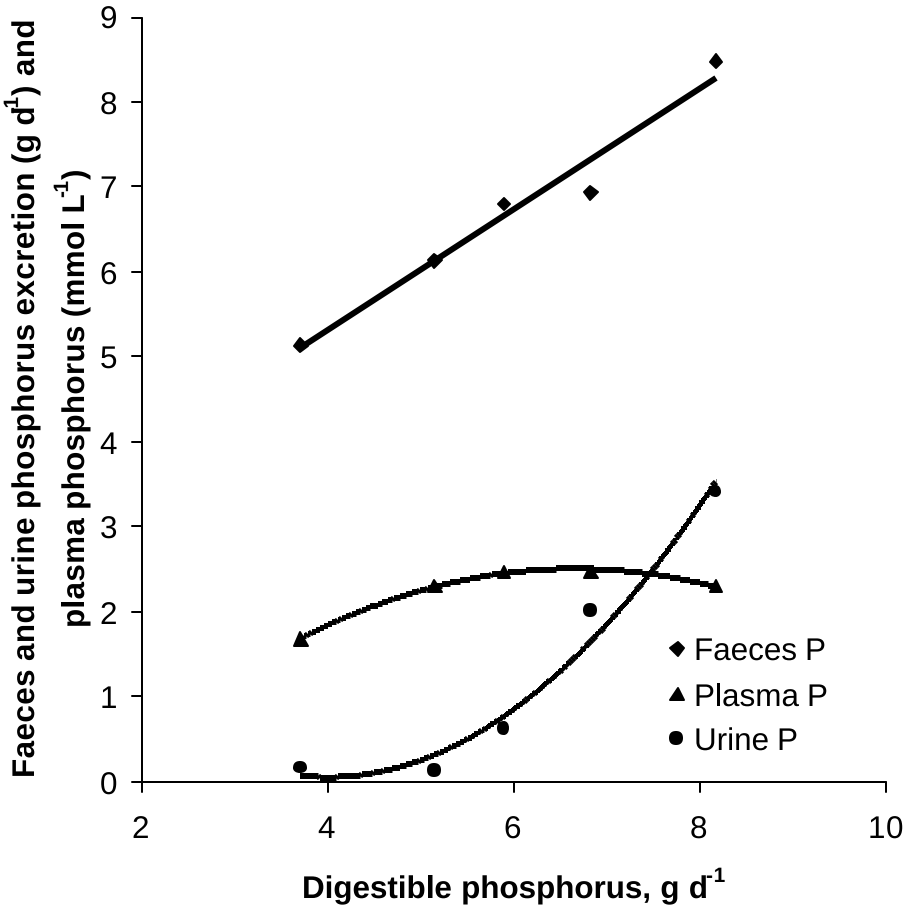

Figure 5. Relationship between digestible phosphorus intake and fecal, urinary and plasma phosphorus (Project 3; Ekpe et al., 2002). Digestible phosphorus requirement was 6 g/d for this project.