Diet Manipulation to Reduce Nutrient Content in Swine Manure

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Executive Summary
Nutrient management is becoming increasingly important for sustainability of the swine industry. Diet manipulation to reduce nitrogen and phosphorus content of swine will be discussed. For example, effects of particle size of the diet, 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, the results indicate that nitrogen and phosphorus excretion patterns can indeed be altered by diet manipulation.

Introduction
The need for a careful nutrient management planning is increasing with intensity of the pork industry, and as public concerns regarding nutrient excretion and odour emissions increase. Successful nutrient management is thus key for sustainable pork production. The two principal nutrients of concern are nitrogen (N) and phosphorus (P). Nitrogen is of concern because of its impact both on the inside and outside barn environment. Swine production has been recognized as a major source of ammonia emission, which is a noxious gas for humans and animals and contributes to bad odour and the 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. 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). 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). Exp. 1 investigated two nutritional strategies, particle size reduction and enzyme supplementation, as a means for reducing N and P excretion from growing pigs. Exp. 2 investigated dietary protein and fermentable fibre as means to alter nitrogen excretion patterns. Exp. 3 investigated P requirements of grower pigs, because a better understanding of P requirements might enable diet formulation closer to pig requirements to reduce the amount of P in manure.

Experimental Procedures
Exp. 1 focussed on dietary particle size and supplemental enzymes. Three particle sizes: 400 (fine), 700 (medium), and 850 μm (coarse); were compared within four enzyme treatments: control (CON), carbohydrase (α-glucanase with xylanase; CHO), phytase (PHY), and PHY with 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 crude protein (1.6 g dLys/Mcal DE). Sixty barrows (25.3 ± 1.4 kg) were housed individually in metabolism pens to obtain 5 observations per treatment. Pigs were fed at 3 times maintenance DE (110 kcal DE/kg BWº.75).

Exp. 2 focussed on dietary protein and fermentable fibre. Two levels of CP (high, 18.5% and low, 15.6%) and three sources of fibre (control, soybean hulls (SH;15%), and sugar beet pulp (SBP; 20%)) were tested in a 2 x 3 factorial design. Diets (wheat, barley, soybean meal and corn starch) were formulated to 3.3 Mcal DE/kg and 2.4 g dLys/Mcal, supplemented with Lys, Met, Trp, Thr, Iso, or Val to maintain a similar content of digestible amino acids. Pigs (30±3kg) 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.
Exp. 3 focussed on the definition of phosphorus requirements based on (among other) phosphorus excretion patterns. Performance and metabolism studies were conducted to evaluate P metabolism and to determine P requirements of grower pigs, using 200 pigs (offspring of Synthetic C-21 sows x Canabrid boars, PIC, Acme, AB; 23 ± 0.9 kg) and 20 barrows (54 ± 3.1 kg), respectively. Five levels of total P (AA, 0.42%; BB, 0.51%; CC, 0.55%; DD, 0.65%; EE, 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−1 and 0.80% digestible lysine.

Results and Discussion

Exp. 1. Fine PS reduced fecal N excretion by 15 and 18% compared to the medium PS and coarse PS diets respectively; while urinary N excretion increased by 13 and 15% with medium PS and fine PS respectively, compared to coarse PS diets (Figure 1; P < 0.05). Fine PS diets reduced total N excretion by 7 and 4% compared to medium PS and coarse PS diets, respectively (P < 0.05). Diets with phytase resulted in 4% less total N excretion that diets without, while diets with carbohydrase lowered fecal N excretion by 5% compared to those without (P < 0.05). Fine PS reduced fecal and total P excretion by 12% compared to medium PS (Figure 2; P < 0.05). Phytase supplementation resulted in a 28% reduction in fecal and total N excretion compared to those without phytase (P < 0.01). Urinary P excretion was insignificant compared to the amount excreted in the feces due to a limited supply of dietary phosphorus.

Exp. 2. Urinary N excretion was 26% lower for low protein compared to high protein diets (Figure 3; P < 0.05). Fecal N increased 14% for soyhulls and 41% for sugarbeet pulp compared to control diet (P < 0.05). Urinary N decreased 37% for soyhulls and sugarbeet pulp compared to control diets (P < 0.01). Retention of N decreased 15% for soyhulls (P < 0.05) and 9% sugarbeet pulp (P < 0.06) compared to control. Expressed as a percentage of N intake, fecal N excretion was increased 6% for soyhulls and 9% for sugarbeet pulp compared to control (Figure 4; P < 0.01). Percentage urinary N excretion was reduced 8% for soyhulls and 10% for sugarbeet pulp compared to control (P < 0.01). Voluntary feed intake and body weight gain and feed efficiency were not affected by dietary treatments (P > 0.10). Results suggest that reduction of protein content is an effective way to reduce N excretion, especially urinary N. Use of fibre sources high in fermentable carbohydrates can shift N excretion from urine (urea N) to feces (protein-bound N), thereby reducing chances of ammonia emission. Although ADG and FE were not affected by reducing dietary CP, further research is required to maintain nitrogen retention.

Exp. 3. Increasing P levels in feeds resulted in increased ADG (P < 0.01), feed intake (P < 0.05) and FE (P < 0.01). Barrows had higher ADG than gilts (0.890 kg d−1 vs. 0.838 kg d−1; P < 0.05). The ADG and FE ranged from 0.726 to 0.907 kg d−1 and 0.407 to 0.467, respectively. The observed growth rates and FE on all treatments were substantially better than those suggested by NRC (1998), except for the growth rate for treatment AA. Phosphorus is needed for development and maintenance of soft and skeletal tissues (Underwood & Suttle 1999), and the low level of P in AA may be responsible for the low growth rate in this group. The observation is consistent with the results of de Lange et al. (1993), who reported that animal performance was slightly reduced at a low Ca and P levels in diet.

As anticipated, increased P intake resulted in increased amount of P in faeces, urine and blood plasma (Figure 5). The reports of Cromwell et al. (1993), Jongbloed et al. (1993) and Liu et al. (1998) support these findings. The total P intake accounted for 92, 89 and 99% of the variations in faecal, urinary and plasma P, respectively. On the whole, it is possible to predict the amounts of P in faeces, urine and blood plasma based on P intake using the polynomial regression equations because of the relatively high r2 values. As the amount of total P in feeds increased, more P is excreted in urine and faeces after maximum levels of plasma P are achieved. These findings demonstrate that the portion of P excreted by pigs is a direct result of feeding excessive levels of P.

Based on P and N metabolism, the available P requirements were 6.24 g d−1 with ADG, 8.29 g d−1 with bone P, 6.70 g d−1 with plasma P, 6.71 g d−1 and 6.01 g d−1 with retained P and N, 4.02 g d−1 and 7.19 g d−1 with faecal P and N, 4.06 g d−1 and 6.03 g d−1 with urinary P and N, respectively (Figure 6). The total and available P requirements for 23-60 kg pigs of mixed gender (1:1 ratio) were 12.30 g d−1 and 6.43 g d−1, respectively. Interestingly, the values of available P requirements obtained for barrows in the performance and metabolism studies are comparable (6.17 g d−1 vs. 6.24 g d−1). The total and available P requirements obtained in the present study are higher than the values, 11.59 g d−1 and 4.89 g d−1.
respectively, indicated by NRC (1998) for 50-80 kg pigs of mixed gender (1:1 ratio), most likely due to a higher than average protein deposition rate. NRC indicated that the daily requirements might be slightly higher than the given values for pigs having high lean growth rates of more than 325 g d⁻¹. In this study, the lean growth was 460 to 540 g d⁻¹. The results are in agreement with results of Carter and Cromwell (1998), who reported that pigs with high lean tissue and protein deposition required higher daily intakes of P than pigs with low lean tissue and protein deposition.

**Conclusions and Implications**

Reducing particle size below 700µm proved effective in altering N excretion patterns, while phytase proved very effective in improving the digestibility of P in the diet. The addition of carbohydrase showed little evidence of reducing total N or P excretion. A reduction of dietary protein content will reduce excretion of nitrogen in feces, but especially in the urine. With dietary fermentable fibre, part of the urinary excretion of nitrogen can be shifted toward excretion in feces. Reduction in amount of P in feeds is effective in reducing P in manure. The success of the management strategy for reducing P excretion is dependent on an accurate estimate of P requirements for pigs. A better understanding of the P requirements might enable diet formulation closer to the pig requirements to reduce the amount of P in manure. An improvement in P 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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**References**


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Red Deer, Alberta, Canada*
Treatments include: diet particle size (fine, medium, and coarse), dietary phytase (PHY) and dietary carbohydrase (CHO).

Figure 1. Total nitrogen excretion (g/day) partitioned by excretory route (Exp. 1).

![Figure 1](image1)

Treatments include: diet particle size (fine, medium, and coarse), dietary phytase (PHY) and dietary carbohydrase (CHO).

Figure 2. Total phosphorus excretion (g/d) partitioned by excretory route (Exp. 1).

![Figure 2](image2)

Treatments include: diet particle size (fine, medium, and coarse), dietary phytase (PHY) and dietary carbohydrase (CHO).

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Figure 3. Effect of dietary protein level on fecal and urinary N excretion and N retention (in g/d; Exp. 2).

Figure 4. Effect of dietary fibre source (SH is soyhulls, SBP is sugarbeet pulp) on fecal and urinary N excretion and N retention (as % of N intake; Exp. 2).
Figure 5. Relationship between phosphorus intake and faecal, urinary and plasma phosphorus (Exp. 3).

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y = 0.03x^2 - 0.29x + 5.55 \\
R^2 = 0.92 \text{ (Faecal)}
\]

\[
y = 0.05x^2 - 0.76x + 2.98 \\
R^2 = 0.89 \text{ (Urinary)}
\]

\[
y = -0.03x^2 + 0.86x - 3.53 \\
R^2 = 0.99 \text{ (Plasma)}
\]

Figure 6. Available phosphorus requirements based on phosphorus and nitrogen metabolism (Exp. 3).