Effects of Reduced Crude Protein and Fiber Supplementation on Nitrogen and Phosphorus Utilization and Availability

D. M. Sholly, D. T. Kelly, S. L. Hankins, M. C. Walsh, M. Cobb,
A. L. Sutton and B. T. Richert
Department of Animal Sciences

Introduction

In recent years, animal agriculture has been surrounded by concerns of environmental contamination and degradation. To reduce potential environmental hazards, researchers have tried various practices to reduce the amount of nutrients being excreted in swine manure and ammonia emissions from manure contributing to diminishing air quality. To prevent further environmental concerns, diet modification has become an alternative to reduce unutilized dietary nitrogen (N) and phosphorus (P).

It is known that as a pig grows, feed intake increases while protein and phosphorus requirements decrease (Pond et al., 1995). To meet these changes in nutrient needs, producers use phase feeding techniques to balance the dietary nutrient concentrations with the nutrient requirements of the pig. Despite this, inefficiencies still exist in the ability of the pig to digest and retain nutrients from formulated diets, with pigs only retaining approximately 56% of the amino acids they consume (NRC, 1998). In this study, reduced crude protein (CP)/high available phosphorus (HAP) corn diets were used along with normal corn/SBM diets to determine their effects on fecal and urine nutrient excretion and total manure production. Wheat bran (WB) was also added to the diets (0 or 10%) to determine the ability of fiber supplementation to sequester ammonia-N and influence changes in manure nutrient content and manure N and P forms during storage.

Materials and Methods

Experimental Design. *s*ixteen crossbred barrows (avg BW = 71.9 lbs) were allotted by weight to four experimental diets (4 pigs/diet). Prior to the experiment, the barrows were allowed a five day adjustment period (d 0 to 5) to the metabolism pens (4 ft x 4 ft). During the adjustment period, a standard grower 1 diet was fed with unlimited access to water. On day 6, the dietary treatments began with restricted access to water, for a 28-day feeding period. Feces and urine were collected three times each week, for 20 days, and placed in sixteen individual, 15 inch diameter by 48 inch tall PVC columns. The manure was collected and stored in the columns for 25 days, and at the end of the collection period were thoroughly mixed with an electric stirrer to obtain a representative sample for analysis. Orts were collected three times each week, placed in a drying oven for 48 to 72 h, and weighed at the following collection time. Additionally, at d 26 a three day total collection of urine and feces was conducted to determine nutrient digestibility and retention of these diets.

Dietary Treatments. dietary treatments (Table 1) were: 1) Control, 17.7% CP; 2) Control plus 10% wheat bran; 3) Low Nutrient Excretion diet (LNE) containing HAP corn, reduced crude protein (13.9%) plus synthetic amino acids, and phytase; and 4) LNE plus 10% wheat bran. During the total collection period, 0.3% chromic oxide was added to all the diets as an indigestible marker.

Statistical analysis. data were analyzed as a 2 x 2 factorial design of dietary crude protein level and wheat bran supplementation level, and their interaction using the GLM procedure of SAS (2001; SAS Institute Inc., Cary, NC).

Sample analysis feces. urine, and stored manure samples were analyzed for dry matter (DM), ash, total Kjeldahl nitrogen (TN), ammonium nitrogen (AmmN), total phosphorus (TP), water soluble phosphorus, potassium (K), volatile fatty acids (VFA), and pH. Diets were analyzed for DM, ash, TN, TP, K, and pH. Water soluble phosphorus and K data are not presented.

Results

There were no differences in initial and final body weights among dietary treatments (Table 2). Wheat bran inclusion decreased feed intake (P < 0.007) and DM intake (P < 0.005) by approximately 9%. Water usage was not different among dietary treatments and averaged 0.79 gal/d; however, the water usage for LNE plus 10% WB treatment was numerically lower than the other diets.

Manure production, on an as-is basis, was not different among dietary treatments (Table 3). However, the total volume (gal.) and pounds of manure produced were numerically lower for the LNE plus 10% WB diet compared to the other three diets. Reducing dietary CP reduced the amount of manure DM produced per day by 19.2% (P < 0.004). Adding 10% WB to the diet, however, increased the amount of manure DM produced per day by 16.4% (P < 0.03). There was a tendency for an interaction between dietary CP and WB for manure DM production per day (P < 0.08), with WB increasing daily production of manure DM in the LNE diet to a greater extent than in the control diet. The manure DM content (%) was affected by the addition of WB to the diets, increasing the percentage of DM by approximately 32% (P < 0.05). There was also an interaction between dietary CP and WB for manure DM content (P < 0.05), with WB again having a greater effect of increasing the percentage of DM in the LNE diet than in the control diet. There was a trend for an interaction of CP and WB for manure ash percentage, on an as-is basis (P < 0.07). The addition of WB increased the manure ash on an as-is basis in the LNE diets, but decreased it in the control diet. In contrast, the addition of WB caused a 14% decrease (P < 0.008) in the percent manure ash on a dry matter-basis (DMB) in both the control and LNE diets, even though the expected result would be an increase in manure ash due to the insoluble protein fraction of the WB. Manure pH was not affected by either dietary CP or WB, averaging 6.9.

Reducing dietary CP tended to decrease TN concentration (as-is basis) in the stored manure by 20% (P<0.09). However, there was a trend (P < 0.10) for an interaction between CP and WB in TN concentration; when WB was added to the control diet, TN (as-is) was reduced, but when WB was added to the LNE diet, TN (as-is) was increased. In contrast, there was a strong effect of CP (P < 0.0001) and WB (P < 0.0001) on the concentrations of TN in the stored manure when expressed on a DMB. By reducing dietary CP and adding WB to the diet, the TN concentration (DMB) decreased by 14.6% and 21%, respectively. Again, there was a tendency (P < 0.11) for an interaction between CP and WB in manure TN concentrations (DMB), due to a greater reduction when WB was added to the LNE diet as compared to the control diet. Reducing dietary CP reduced (P < 0.0001) the amount of TN excreted when expressed both in grams and grams per day by 32%.

Ammonium N concentration, on an as-is basis, was not different among dietary treatments. However, the concentration of AmmN (DMB) was decreased (P < 0.003) by the inclusion of WB by 22.4% in the stored manures. Reducing dietary CP decreased ($P < 0.008$) the amount of AmmN (g and g/d) present in the stored manure by 27.7%.

The reduction of dietary CP and phosphorus with the LNE diet decreased ($P < 0.003$) the TP concentration (as-is basis) of the stored manure, lowering the TP concentration by 38% compared to the control diet. The concentration of TP, on a DMB, was also reduced 39% ($P < 0.0001$) by feeding the LNE diet compared to the control diet. The amount of TP produced in grams ($P < 0.0001$) and grams per day ($P < 0.0001$) were decreased by 49.6% and 49.4%, respectively, by feeding the LNE diet. There was an interaction ($P < 0.02$) between dietary CP and WB on the concentration of TP on both an as-is basis and DMB, and the amount of TP produced (g and g/d). The inclusion of WB to the control diet decreased all phosphorus parameters, but when WB was added to the LNE diet, all phosphorus measure increased.

Reducing CP or supplementing the diet with WB did not significantly affect the concentration of volatile fatty acids produced in the stored manure (Table 4). There was a tendency ($P < 0.07$) for an interaction between CP and WB for isobutyrate concentration (mmol/L); when WB was added to the control diet, isobutyrate concentration decreased, but when WB was added to the LNE diet, isobutyrate increased.

Discussion

During this study the inclusion of WB did decreased feed intake by 9%, however, the amount of manure produced (expressed in gal or lb) was not significantly different from the diets without WB. Water usage was also not different among dietary treatments. The amount of manure DM (lb/d) was increased with the addition of WB by 16.4%, while reduced CP levels decreased manure DM (ld/d) by 19.2%. There was a trend for an interaction between CP and WB for manure DM production (lb/d), with WB having a greater effect on manure DM production (lb/d) from pigs fed the LNE diet compared to the control diet. This may be explained by WB's addition of fibrous and non-digestible fractions to the LNE diet, which was designed to reduce/minimize DM excretion compared to the control diet. This can again be seen with a 32% increase in manure DM (%) with the addition of WB. One would have also expected a change due to the fiber addition from the WB to enhance hindgut and manure storage fermentation. However, there were no differences in manure pH among dietary treatments. The lack of pH change is verified by the lack of change in VFA concentrations as well, which would have been expected with these fibrous additions.

Otto et al. (2003) stated that by reducing dietary CP intake, reductions in N excreted would be possible. This was evident in this trial, where total nitrogen concentration (DMB) in the stored manure column was decreased by 14.6% when CP was decreased. This decrease in TN concentration was in fact due to the reduced soybean meal and amino acid content of the LNE treatments. The amount of TN produced (expressed in g and g/d) was also affected by dietary modification of protein content, and decreased by approximately 32%, with the fibrous addition of the WB not affecting daily N excretion.

Wheat bran's ability to sequester AmmN was not observed in this study, with WB not increasing AmmN and TN in the stored manures. Wheat bran actually decreased the concentration of AmmN (DMB) by 22.4% in the stored manures, while reducing dietary CP also decreased the amount of AmmN (g and g/d) by 27.7%. The concentration and production of TN and AmmN in manure from pigs fed the control diet was higher, when the TN and AmmN should have been lower when compared to the control plus 10% WB diet. However, the LNE diet does not follow the same pattern. Manure from pigs fed the LNE plus 10% WB was higher in TN concentration on both an as-is basis and DMB when compared to the LNE diet. The AmmN (as-is) content of LNE plus 10% WB diet was numerically higher than the LNE diet, but not significantly different.

Because of wheat bran's natural phytase and fiber content a decrease in excreted phosphorus was expected due to the release of more phytic phosphorus. Looking within each set of diets, the control plus 10% WB diet followed the trend of reducing P excretion compared to the control diet without WB. On the other hand, the LNE plus 10% WB diet had a numerical increase in the excretion and concentration of total phosphorus. Reducing crude protein and dietary phosphorus with the LNE diets did significantly alter the concentration of TP (as-is and dry matter basis) in the store manure, decreasing by 38% and 39%, respectively. The amount of TP produced (g and g/d) was also decreased by approximately 48.3%. The decrease in concentration and excreted phosphorus was primarily a result of a 35.8% reduction in dietary phosphorus concentration with the LNE diets than the inclusion of WB.

Implications

This study indicates that reductions in TN and AmmN concentrations are possible with the addition of 10% wheat bran in formulated diets. This study also presents and supports the idea that reducing dietary crude protein and phosphorus levels in the diet causes a decrease in the amount of manure DM produced (lb/d), and a reduction in TN, ammonium N, and TP excreted in the manure.

Acknowledgement

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References

NRC (National Research Council). 1998. Nutrient requirements of swine (10th ed.). National Academy Press, Washington, D.C.

Otto, E.R., M. Yokoyama, P.K. Ku, N.K. Ames, and N.L. Trottier. 2003. Nitrogen Balance and ileal amino acid digestibility in growing pigs fed diets reduced in protein concentration. J. Anim. Sci. 80: 1743-1753.

Pond, W.G., D.C. Church, and K.R. Pond. Basic Animal Nutrition and Feeding (4th ed.) New York: John Wiley & Sons, Inc., 1995.

Table 1. Ingredient, calculated, and analyzed composition of dietary treatments

Diet Type	**Control**		**LNE**	
Wheat Bran Inclusion	**0**	**10%**	**0**	**10%**
Ingredient, %				
Corn	71.57	58.42	-----	-----
HAP Corn	-----	-----	81.81	68.80
SBM, 48% CP	24.50	25.5	14.3	15.00
Wheat Bran	-----	10.00	-----	10.00
Swine Grease	1.00	3.38	1.00	3.40
Limestone	0.85	1.10	1.36	1.33
Dicalcium Phosphate	1.25	0.77	-----	-----
Vitamin Premix[a]	0.15	0.15	0.15	0.15
TM Premix+ Se 600[b]	0.13	0.13	0.13	0.13
Phytase	-----	-----	0.075	0.075
Salt	0.35	0.35	0.35	0.35
Lysine-HCl	0.10	0.10	0.46	0.475
DL-Methionine	-----	-----	0.075	0.05
L-Threonine	-----	-----	0.145	0.12
L-Tryptophan	-----	-----	0.038	0.02
CTC-50	0.10	0.10	0.10	0.10
Chromic Oxide[c]	0.30	0.30	0.30	0.30
Calculated Analysis				
Metabolizable Energy, kcal/lb	1522	1522	1524	1523
Crude Protein, %	17.66	18.61	13.94	14.78
Calcium, %	0.70	0.71	0.60	0.60
Phosphorus, %	0.60	0.60	0.34	0.43
Available Phosphorus, %	0.30	0.24	0.18	0.19
Lysine, %	1.00	1.06	1.00	1.07
Methinonie + Cysteine, %	0.60	0.63	0.57	0.57
Threonine, %	0.66	0.69	0.64	0.65
Tryptophan, %	0.20	0.22	0.18	0.18
Isoleucine, %	0.73	0.76	0.54	0.57
Valine, %	0.84	0.88	0.64	0.68
Analyzed Composition				
CP, %	16.53	17.84	12.77	13.86
P, %	0.53	0.56	0.30	0.42

[a]Vitamin premix supplied per lb of diet: vitamin A, 1650 IU; vitamin D3, 165 IU; vitamin E, 12.0 IU; Menadione, .54 IU; vitamin B_{12}, 9.5 IU; Riboflavin, 1.93 IU; d-Pantothenic Acid, 6.0 IU; Niacin, 9.0 IU.

[b]TM premix supplied per lb of diet: Iron, 38.5 mg; Zinc, 38.5 mg; Manganese, 4.77 mg; Copper, 3.6 mg; Se, 136 mg.

[c]Chromic Oxide was added during total collection period at expense of corn

Table 2. Effect of dietary crude protein (CP) level and wheat bran (WB) inclusion on pig performance and water usage during a 25-day manure generation

Diet Type	Control		LNE			Significance, P <		
Wheat Bran	0	10%	0	10%	SE	CP	WB	CP x WB
Average initial wt., lb	71.63	72.38	72.25	71.50	4.12	0.98	1.00	0.86
Average final wt., lb	124.75	117.25	124.25	120.75	5.67	0.80	0.35	0.73
Feed Intake, lb/d as-is	4.32	3.95	4.51	4.11	0.12	0.16	0.007	0.88
DM intake, lb/d	3.85	3.50	3.98	3.62	0.10	0.24	0.005	0.94
Water Usage, gal	22.58	24.15	24.01	17.41	2.52	0.33	0.36	0.15
Water Usage, gal/d	0.81	0.86	0.86	0.62	0.10	0.33	0.35	0.16
Diet, % DM	89.13	88.54	88.38	88.14	-----	-----	-----	-----
Diet, % Ash as-is	5.06	4.31	3.36	4.57	-----	-----	-----	-----
Diet, % Ash DMB	5.68	4.87	3.80	5.18	-----	-----	-----	-----
Diet pH	5.69	5.92	5.93	5.94	-----	-----	-----	-----
Diet N, %	2.64	2.85	2.04	2.22	-----	-----	-----	-----
Diet P, %	0.53	0.56	0.30	0.42	-----	-----	-----	-----

Table 3. Effect of dietary crude protein (CP) level and wheat bran (WB) inclusion on manure generation and composition over a 25 day collection period

Diet Type	**Control**		**LNE**			**Significance, P <**		
Wheat Bran	**0**	**10%**	**0**	**10%**	**SE**	**CP**	**WB**	**CP x WB**
Manure generation								
Total Volume, gal	13.10	14.73	12.62	9.85	1.60	0.12	0.73	0.19
Manure, lb	111.56	119.45	107.60	80.11	14.14	0.15	0.50	0.23
Manure, lb/d	4.46	4.78	4.31	3.20	0.57	0.15	0.50	0.24
Manure DM, lb/d	0.36	0.37	0.25	0.34	0.02	0.004	0.03	0.08
Manure DM, %	8.58	8.50	5.94	10.66	1.08	0.83	0.05	0.05
Manure Ash %, as-is	2.10	1.90	1.52	2.27	0.23	0.65	0.26	0.07
Manure Ash %, DMB	24.97	22.24	25.68	21.30	0.80	0.88	0.008	0.32
Manure pH	7.01	6.80	7.10	6.72	0.18	0.98	0.14	0.64
Nitrogen								
TN %, as-is	1.00	0.84	0.63	0.84	.102	0.09	0.80	0.10
TN %, DMB	11.78	9.93	10.68	7.87	.278	0.0001	0.0001	0.11
TN, g	479.3	417.8	305.3	304.8	24.23	0.0001	0.23	0.23
TN, g/d	19.2	16.7	12.2	12.2	0.97	0.0001	0.23	0.24
Ammonium nitrogen								
AmmN %, as-is	0.61	0.53	0.42	0.55	.073	0.26	0.74	0.18
AmmN %, DMB	7.35	6.15	7.17	5.11	.430	0.18	0.003	0.34
AmmN, g	299.4	259.6	204.5	199.8	24.26	0.008	0.38	0.48
AmmN, g/d	12.0	10.4	8.2	8.0	0.98	0.008	0.39	0.47
Phosphorus								
TP %, as-is	0.23	0.20	0.086	0.18	.022	0.003	0.13	0.02
TP %, DMB	2.72	2.45	1.46	1.70	.099	0.0001	0.90	0.02
TP, g	110.40	102.87	41.57	66.05	5.79	0.0001	0.17	0.02
TP, g/d	4.4	4.1	1.7	2.7	0.24	0.0001	0.17	0.02

Table 4. Effect of dietary crude protein (CP) level and wheat bran (WB) inclusion on stored manure volatile fatty acid (VFA) concentration

Diet Type	**Control**			**LNE**		**Significance, P <**		
Wheat Bran	**0**	**10**	**SE**	**CP**	**SE**	**CP**	**WB**	**CP x WB**
VFA, mmol/L								
Acetate	189.2	163.8	121.8	174.8	25.58	0.29	0.60	0.15
Propionate	60.8	49.1	39.4	58.3	11.46	0.60	0.76	0.21
Isobutyrate	7.0	6.1	4.7	6.8	0.74	0.29	0.43	0.07
Butyrate	63.8	67.9	46.1	63.8	13.10	0.42	0.42	0.61
Isovalerate	4.4	4.4	3.6	4.3	0.67	0.50	0.59	0.62
Valerate	8.6	5.3	4.1	5.8	1.77	0.27	0.68	0.19
Total	333.8	296.7	219.6	313.6	44.68	0.30	0.54	0.17