SHORT COMMUNICATION

Effects of dietary crude protein level and sugar beet pulp inclusion on nitrogen excretion patterns in grower and finisher pigs

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Smith, L. F., Lemay, S. P., Patience, J. F. and Zijlstra, R. T. 2004. **Effects of dietary crude protein level and sugar beet pulp inclusion on nitrogen excretion patterns in grower and finisher pigs.** Can. J. Anim. Sci. **84**: 717–720. Diets with high and low protein content and with or without sugar beet pulp (SBP) were tested in grower and finisher pigs; SBP replaced wheat in grower and barley in finisher pig diets. Urinary N was lowered ($P < 0.05$) and faecal N not affected ($P > 0.10$) by low-protein diets. In grower pigs, SBP lowered urinary N ($P < 0.05$) and interacted with dietary protein ($P < 0.10$). In finisher pigs, SBP did not affect N excretion patterns ($P > 0.10$). Reduced dietary protein consistently reduced urinary N excretion, whereas effects of SBP inclusion were dependent on dietary protein content or replaced cereal grain.

Key words: Excretion, fibre, nitrogen, pigs, protein

Smith, L. F., Lemay, S. P., Patience, J. F. et Zijlstra, R. T. 2004. **Incidence de la concentration de protéines brutes alimentaires et de l'inclusion de pulpe de betterave sucrière sur l'excrétion d'azote par les porcs en croissance et de finition**. Can. J. Anim. Sci. **84**: 717–720. Les auteurs ont testé des rations à forte ou faible concentration de protéines et avec ou sans pulpe de betterave sucrière (PBS) sur des porcs en croissance et des porcs de finition; la PBS remplaçait le blé dans la ration des porcs en croissance et l'orge dans celle des animaux de finition. Les rations à faible teneur en protéines réduisent la concentration de N dans l'urine ($P < 0,05$) mais celle dans les fèces n'est pas touchée ($P > 0,10$). Chez les animaux en croissance, la PBS diminue la concentration de N dans l'urine ($P < 0,05$) et interagit avec les protéines des aliments ($P < 0,10$). Chez les porcs de finition, la PBS ne modifie pas l'excrétion du N ($P > 0,0$). Une plus faible concentration de protéines réduit toujours l'excrétion de N dans l'urine, alors que l'incidence de la PBS dépend de la teneur en protéines des aliments ou de la quantité de céréales remplacée.

Mots clés: Excrétion, fibres, azote, porcs, protéines

Nitrogen emitted as ammonia from swine manure can negatively affect air quality inside and outside the barn. Dietary manipulations may alter N excretion patterns, and subsequently reduce ammonia emissions. Lowering dietary protein content while balancing for digestible amino acids using synthetic amino acids will reduce urinary N excretion (Zervas and Zijlstra 2002) and ammonia emissions (Canh et al. 1998a). Likewise, dietary fermentable fibre such as SBP may shift N excretion from urea in urine to less volatile microbial protein in faeces (Zervas and Zijlstra 2002) and reduce slurry pH, thereby reducing ammonia emissions (Canh et al. 1998b).

The adoption of single or combined dietary manipulations such as low-protein diets or fermentable fibre might be encouraged in commercial swine production if protein deposition rates are not affected negatively. The effects of low-protein diets and SBP on reducing urinary N excretion may be additive (Zervas and Zijlstra 2002); however, limited research has been conducted to examine their combined effects on N excretion in pigs with different body weights fed commercial diets.

The study objective was to determine the effects of low-protein diets or SBP inclusion on N excretion patterns in grower and finisher pigs with free access to feed. Pigs were fed non-purified diets based on wheat for grower pigs and wheat and barley for finisher pigs to reflect typical commercial diet formulations.

In two trials (Trial 1, grower pigs; Trial 2, finisher pigs), two dietary CP levels (high and low), a fermentable fibre source (SBP) and a control were examined in a 2 × 2 factorial arrangement for a total of four mash diets (Table 1). The

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Abbreviations: **CP**, crude protein; **DE**, digestible energy; **SBP**, sugar beet pulp

Table 1. Ingredient and nutrient composition of diets for grower and finisher pigs (as-fed basis)

	Trial 1 - Grower pigs[z]				Trial 2 - Finisher pigs[y]			
	High protein		Low protein		High protein		Low protein	
Ingredient (%)	Control	SBP	Control	SBP	Control	SBP	Control	SBP
Wheat	78.15	58.03	84.82	64.71	63.29	58.32	62.38	64.95
Barley	–	–	–	–	22.72	10.00	29.06	10.00
Sugar beet pulp	–	15.00	–	15.00	–	15.00	–	15.00
Soybean meal	16.52	21.09	8.96	13.50	6.53	9.23	–	1.77
Canola meal	–	–	–	–	3.00	3.00	3.00	3.00
Canola oil	1.13	1.99	1.54	2.39	1.00	1.20	1.73	1.61
Di-calcium phosphate	1.06	1.18	1.20	1.32	0.62	0.77	0.74	0.90
Limestone	0.83	0.50	0.83	0.50	0.74	0.43	0.73	0.43
Mineral premix[x]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[w]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Acid-insoluble ash	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Lysine-HCl	0.33	0.24	0.53	0.45	0.18	0.13	0.36	0.34
L-Threonine	0.08	0.06	0.17	0.15	0.02	0.02	0.10	0.10
DL-Methionine	–	0.01	0.03	0.06	–	–	–	–
L-Tryptophan	–	–	0.02	0.02	–	–	–	–
Nutrients (analysed)								
Crude protein (%)	20.7	20.4	18.4	18.4	17.9	17.3	15.0	15.0
Acid detergent fibre (%)	3.00	7.40	4.05	6.55	4.85	8.70	4.55	8.00
Neutral detergent fibre (%)	19.60	22.90	18.40	24.00	22.50	23.80	21.60	23.80

[z]Formulated to 20.0 and 18.0% CP (high and low, respectively), 0.60% total P, and 0.70% Ca.
[y]Formulated to 17.0 and 15.0% CP (high and low, respectively), 0.50% total P, and 0.60% Ca.
[x]Supplied per kilogram of diet: Zn, 100 mg as zinc sulphate; Fe, 80 mg as ferrous sulphate; Cu, 50 mg as copper sulphate; Mn, 25 mg as manganous sulphate; I, 0.5 mg as calcium iodate; Se, 0.1 mg as sodium selenite.
[w]Supplied per kilogram of diet: vitamin A, 8250 IU; vitamin D_3, 825 IU; vitamin E, 40 IU; niacin, 35 mg; D-pantothenic acid, 15 mg; riboflavin, 5 mg; menadione, 4 mg; folic acid, 2 mg; thiamine, 1 mg; D-biotin, 0.2 mg; vitamin B_{12}, 0.025 mg.

main ingredients were wheat, barley, soybean meal, canola meal, and SBP; acid-insoluble ash (Celite, Advanced Minerals, Goleta, CA) was included as an indigestible marker. The SBP replaced wheat in Trial 1 and barley in Trial 2. Diets were formulated based on digestible energy (DE) and apparent ileal digestible amino acids to contain 3.40 and 3.30 Mcal DE kg^{-1} and 2.65 and 1.85 g digestible lysine $Mcal^{-1}$ DE for Trial 1 and 2, respectively. Synthetic amino acids were included to achieve an ideal amino acid balance (National Research Council 1998), and minerals and vitamins were included to meet or exceed requirements (NRC 1998).

The University of Saskatchewan Committee on Animal Care and Supply approved the experimental protocol. For each trial, 20 barrows (Camborough-22 × Line 65; Pig Improvement Canada, Acme, AB) were selected (Trial 1, 42.8 ± 2.7 kg; Trial 2, 78.9 ± 7.7 kg). Pigs assigned to SBP diets were selected from pigs that had been fed a 7.5% SBP diet for 14 d prior to the experimental periods to enhance adaptation to high SBP diets. Pigs assigned to control diets were selected from pigs that had been fed a standard grower pig (Trial 1, 3.50 Mcal DE kg^{-1} and 3.30 g digestible lysine $Mcal^{-1}$ DE) or finisher pig (Trial 2, 3.30 DE Mcal kg^{-1} and 1.85 g digestible lysine $Mcal^{-1}$ DE) diet. Five barrows were randomly allotted to each diet. The trials lasted 18 d, consisting of a 14-d adaptation to experimental diets and metabolism pens, and a 4-d collection of faeces and urine.

The metabolism pens measured 1.5 × 1.5 m and allowed freedom of movement. Galvanized steel trays and screens were fitted under the pens to collect urine and prevent feed and faeces contamination. Throughout the trials, feed was supplied ad libitum in mash form and water was supplied ad libitum. During the 4-d collections, faeces were collected quantitatively twice daily for Trial 1 and three times daily for Trial 2. Faeces were collected using plastic bags attached to the skin around the anus, and stored at –20°C. Excreted urine fell by gravity through the flooring and drained into a 4-L bottle containing 20 mL of 12 N HCl to lower the pH of urine and prevent volatilization of urinary N. Urine was collected twice daily, weighed, and a 5% sub-sample (by weight) was stored at –20°C. Feed and freeze-dried faeces were ground through a 1-mm screen and then analysed for moisture [method 930.15; Association of Official Analytical Chemists (AOAC) 1990] and acid-insoluble ash (McCarthy et al. 1974). Feed, faeces and urine were analysed for N by combustion (method 968.06; AOAC 1990) using a Leco N determinator (model FP-528, Leco Co., St Joseph, MI). Feed was analysed for acid detergent fibre (method 973.18; AOAC 1990) and neutral detergent fibre.

The individual pig was considered the experimental unit. Variables were analysed by analysis of variance as a 2 × 2 factorial arrangement using the general linear models procedure of the SAS Institute, Inc. (1996). The statistical model included effects for dietary treatment (CP, SBP, and CP × SBP), and initial body weight as covariate for Trial 2. Means were separated using the probability of difference ($P < 0.05$). Data were reported as least-square means.

For grower pigs, dietary protein level affected N intake ($P < 0.05$); pigs fed high-protein diets consumed 11.8%

Table 2. Effect of dietary protein level and sugar beet pulp (SBP) inclusion on N balance and apparent total-tract nutrient digestibility in grower (Trial 1) and finisher (Trial 2) pigs

	High protein		Low protein			*P* value for		
Variable[z]	Control	Sugar beet pulp	Control	Sugar beet pulp	Pooled SEM	Protein	Sugar beet pulp	Protein × Sugar beet pulp
Grower pigs								
N intake (g d^{-1})[y]	75.2	74.2	64.5	67.3	2.2	0.001	NS[x]	NS
N excretion (g d^{-1})								
Faeces	11.9	14.1	10.7	12.4	0.7	0.062	0.019	NS
Urine	39.3	28.2	27.2	27.0	2.6	0.021	0.043	0.051
Total	51.3	42.2	37.9	39.4	2.7	0.009	NS	0.071
N retention (g d^{-1})	23.9	31.9	26.6	27.9	2.5	NS	0.076	NS
Urinary/faecal N	3.4	2.0	2.6	2.2	0.3	NS	0.006	NS
Finisher pigs								
N intake (g d^{-1})[w]	85. 5	90.9	82.1	77.9	2.4	0.004	NS[x]	0.059
N excretion (g d^{-1})								
Faeces	18.6	20.3	17.3	17.8	1.2	NS	NS	NS
Urine	42.7	40.3	35.7	31.7	3.3	0.031	NS	NS
Total	61.4	60.6	52.9	49.5	3.7	0.018	NS	NS
N retention (g d^{-1})	24.1	30.4	29.1	28.3	3.8	NS	NS	NS
Urinary/faecal N	2.3	1.9	2.1	1.8	0.2	NS	NS	NS

[z]Means are least-square means based on five pigs per treatment.
[y]Nitrogen intake calculated based on average daily feed intake during the 4-d collection: 2269 and 2275 g d^{-1} for high protein control and SBP and 2189 and 2285 g d^{-1} for low protein control and SBP, respectively.
[x]NS, not significant ($P > 0.10$).
[w]Nitrogen intake calculated based on average daily feed intake during the 4-d collection: 2983 and 3278 g d^{-1} for high protein control and SBP and 3415 and 3257 g d^{-1} for low protein control and SBP, respectively.

more N than pigs fed low-protein diets (Table 2). Faecal N excretion was 14.4% higher for SBP than control diets ($P < 0.05$) and 11.3% higher for high-protein than low-protein diets ($P < 0.10$). Dietary protein ($P < 0.05$), SBP ($P < 0.05$), and a protein × SBP interaction ($P = 0.051$) affected urinary N excretion. Overall, pigs fed low-protein diets excreted 20% less urinary N than pigs fed high-protein diets, and pigs fed SBP diets excreted 17% less urinary N than pigs fed control diets. The protein × SBP interaction occurred because, with the inclusion of SBP, pigs fed the high-protein diet had a 28% decrease in urinary N, whereas pigs fed the low-protein diet had less than a 1% decrease.

Dietary protein ($P < 0.05$), a protein × SBP interaction ($P < 0.10$), but not SBP ($P > 0.10$) affected total N excretion. Pigs fed low-protein diets excreted 17.4% less N than pigs fed high-protein diets. The protein × SBP interaction occurred because, with SBP inclusion, pigs fed the high-protein diet had an 18% lower total N excretion, whereas pigs fed the low-protein diets had a 4% higher total N excretion. The N retention was increased 15.6% by SBP inclusion ($P < 0.10$), but not affected by dietary protein ($P > 0.10$). The ratio of urinary to faecal N was decreased 28.7% by SBP inclusion ($P < 0.05$) and was not affected by dietary protein ($P > 0.10$).

For finisher pigs, dietary protein level ($P < 0.05$) and a dietary protein × SBP interaction ($P < 0.10$) affected N intake (Table 2). Overall, pigs fed high-protein diets consumed 9.3% more N than pigs fed low-protein diets ($P < 0.05$). For high-protein diets, SBP inclusion increased N intake 5.5 g d^{-1}, while SBP inclusion decreased N intake 4.2 g d^{-1} in the low-protein diets, thereby causing the interaction ($P < 0.10$). Faecal N excretion was not affected by dietary protein or SBP ($P > 0.10$; Table 2). Urinary and total N excretions were affected by dietary protein ($P < 0.05$), but not by SBP ($P > 0.10$). Pigs fed low-protein diets excreted 19% less urinary N and 16% less total N than pigs fed high-protein diets. Nitrogen retention and ratio of urinary to faecal N were not affected by dietary protein or SBP ($P > 0.10$).

In the present study, dietary protein level and SBP inclusion reduced urinary N excretion in grower pigs. The inclusion of SBP shifted N excretion from urine to faeces, but interacted with dietary protein level resulting in a lesser shift with low-protein diets. In finisher pigs, low-protein diets reduced urinary N and total N excretion, while SBP inclusion did not affect N excretion patterns. Low-protein diets or SBP inclusion did not reduce N retention.

The reduced urinary and total N excretion by lowering dietary protein was similar to reports by Canh et al. (1998a) and Zervas and Zijlstra (2002). Urine is the main excretory pathway for excess N, so a reduction in dietary protein should lower urinary N excretion, provided the consumed protein is balanced correctly for essential amino acids and non-essential amino N. Reduced urinary N excretion caused most of the reduction of total N excretion for pigs fed low-protein diets, because faecal N excretion was only marginally reduced. Lowering dietary protein did not decrease N retention, providing further evidence that low-protein diets can be incorporated successfully into commercial swine production.

Including SBP shifted N excretion from urine to faeces in grower but not finisher pigs. Sugar beet pulp is rich in carbohydrates such as hemicellulose and pectin (Kreuzer et al. 1998) that are not digested by porcine enzymes, but are used as fermentation substrates by intestinal microflora. Large intestine fermentation of SBP is substantial, based on differences between ileal and total-tract digestibility (Mroz et al. 2000). A shift in N excretion from urine to faeces may lower ammonia emissions for two reasons. First, undigested protein entering the large intestine is partly converted to ammonia, then absorbed, transformed into urea in the liver, and excreted in urine (Mosenthin et al. 1992). Intestinal microflora utilize undigested fibre (SBP) and ammonia as energy and N sources, respectively, for microbial protein synthesis. Consequently, less ammonia is absorbed and excreted in urine as urea; instead ammonia is incorporated into microbial protein and excreted in faeces. Faecal N volatilises slower to ammonia than urinary urea, which is rapidly degraded to ammonium by microbial urease (Mroz et al. 2000). Thus, SBP inclusion lowers ammonia emissions by reducing ammonium concentration in slurry. Second, bacterial fermentation of SBP produces volatile fatty acids that, if not absorbed by the pig for energy, will reduce slurry pH (Canh et al. 1998b), thereby reducing ammonia emission.

In the present study, SBP inclusion did not affect N excretion patterns for finisher pigs, possibly explained by the ingredient composition of diets. The SBP replaced wheat for grower pigs but replaced barley for finisher pigs. Barley contains more neutral detergent fibre than wheat, and SBP replacing barley led to similar neutral detergent fibre contents between control and SBP diets. The lack of changes in N excretory patterns when SBP replaced barley is in contrast to observed changes when SBP replaced wheat (Zervas and Zijlstra 2002) or tapioca (Canh et al. 1998b). Barley and SBP may thus have a similar fermentative potential. Indeed, the ratio of urinary to faecal N excretion for finisher pigs fed control diets was similar to the ratio for grower pigs fed SBP diets, indicating that N excretion for finisher pigs had already shifted from urine to faeces without the inclusion of SBP. A reduced ratio of urinary to faecal N may reduce ammonia emissions (Canh et al. 1998a), and may thus be accomplished as well using barley.

The present study was a factorial arrangement to determine combined effects of low-protein diets and SBP inclusion. Previously, a 10-wk study with grower and finisher pigs revealed a 42% reduction in ammonia emissions using a low-protein SBP diet (Payeur 2003), suggesting that urinary N excretion was reduced substantially by combining approaches. Additional research has indicated that the effects of low-protein and SBP inclusion on reducing urinary N excretion were additive (Zervas and Zijlstra 2002). However, the same conclusion cannot be reached from the present study due to interactions between dietary protein level and SBP inclusion for N balance data for grower pigs, and the lack of SBP effects for finisher pigs. For grower pigs, the shift in N excretion from urine to faeces following SBP inclusion was less apparent in low versus high-protein diets. In pigs fed low-protein diets, less undigested N enters the large intestine for potential use in bacterial protein synthesis, due to decreased dietary protein and increased N digestibility by using increased levels of synthetic amino acids. With less excess N in the large intestine of pigs fed low-protein diets, microbial protein synthesis may not be as efficient. Therefore, the shift in N excretion from urine to faeces caused by SBP inclusion may be less apparent in low-versus high-protein diets.

The present study confirmed that dietary manipulations are able to alter N excretion patterns, especially for urinary N, without reducing protein deposition. Lowering dietary protein reduced urinary N excretion, and SBP inclusion may shift N excretion from urine to faeces. Interestingly, SBP inclusion did not shift N excretion patterns for finisher pigs, suggesting that other feed ingredients such as barley may also function to shift N excretion. In contrast to previous studies, SBP inclusion in grower pig diets tended to interact with dietary protein for urinary N suggesting that SBP inclusion may be less effective for low-protein diets. Effects of low protein diets and SBP inclusion to reduce urinary N excretion are thus not additive in all circumstances. Still, low-protein diets with SBP included are likely to reduce ammonia emissions and thereby reduce the impact of swine production on the environment.

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