Effect of Nonstarch Polysaccharide-Rich By-Product Diets on Nitrogen Excretion and Nitrogen Losses from Slurry of Growing-Finishing Pigs

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ABSTRACT : An experiment was conducted to investigate the effect of diet for growing-finishing pigs with high level of non-starch polysaccharides (NSP) from by-products on nitrogen excretion and nitrogen losses from slurry during storage. Sixteen commercial crossbred barrows of about 68 kg BW were randomly allotted to one of four diets. The control diet was formulated using tapioca and rice as basal energy sources. In the other diets, tapioca was replaced by either coconut expellar, rice bran or beer by-product. The diets differed mainly in the amount and compostition of NSP. After a 12-day adaptation period, urine and faeces were collected separately in metabolism cages for 9 days. Urine and faeces from the first four days were used to analyse the nitrogen partitioning. Urine and faeces from the last 5 days were mixed as slurry. The slurry was sampled at the end of the collection period and again after 30 days storage, to analyse for nitrogen to calculate the losses. Increasing dietary NSP reduced urinary nitrogen and nitrogen losses from the slurry during storage. The pigs fed the diet based on beer by-product excreted the most nitrogen via faeces and the least nitrogen via urine. Nitrogen losses from slurry of pigs fed the beer by-product were from 34 to 65% lower than from the other three diets. It is concluded that including NSP-rich by-products in the diet of growing-finishing pigs reduces urinary nitrogen excretion and nitrogen losses from slurry during storage. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 573-578*)

Key Words : Pig, By-product, Polysaccharides, Nitrogen, Slurry, pH

INTRODUCTION

Farms in Vietnam are generally mixed, with both crop and animal husbandry (Hai and Nguyen, 1997). Pig production is not only a major protein source for human consumption but the manure from it is also important in supplying organic fertiliser. It has long been known that much nitrogen is lost while manure is being stored or spread on arable land (Muck and Steenhuis, 1981; Sommer and Thomsen, 1993). Volatilisation of ammonia is the main cause of these nitrogen losses (Muck and Steenhuis, 1981, Maeda and Matsuda, 1997). Ammonia lost from slurry not only reduces fertiliser value, but may also cause pollution of ground water and air (Freney et al., 1983; Apsimon and Kruse-Plass, 1990). The ammonium content and pH of slurry are important factors influencing the ammonia volatilisation from the slurry (Freney et al., 1983; Canh et al., 1997). According to Jongbloed and Lenis (1992), of the total ingested nitrogen by pigs, about 20% is excreted via faeces and about 50% in urine. Nitrogen excreted via faeces is predominately incorporated in bacterial protein, which is less susceptible to rapid decomposition. Nitrogen excreted via urine is mainly in the form of urea, which is easily converted into ammonia and carbon dioxide by the enzyme urease present in faeces. There are two basic ways to reduce the nitrogen excretion in pig urine: 1) by reducing nitrogen content of the diet (Spieker, 1992; Gatel and Grosjean, 1992; Kay and Lee, 1997), 2) by shifting nitrogen excretion from urine to faeces by including non-starch polysaccharides (NSP) in the diet (Schulze et al., 1993; Canh et al., 1997). Furthermore, NSP may influence the pH and ammonia volatilisation from slurry by volatile fatty acid (VFA) formation (Canh et al., 1996 and 1997). So far, however, the concept of including NSP-rich by-products in the diet to reduce nitrogen losses from the slurry has not been fully explored. Therefore, the objective of this study was to investigate the effect of NSP-rich diets for growing-finishing pigs based on by-products on nitrogen excretion and nitrogen losses from slurry during storage.

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MATERIALS AND METHODS

Animal and housing

A total of 16 commercial crossbred barrows (Vietnamese Mongcai × Large white), with initial BW of 67.92±0.58 kg were randomly allotted to one of four diets (table 1). From 60 kg onwards the animals were kept in groups and were fed treatment diets. When the animals reached 65 kg body weight, they were housed individually in a controlled room in metabolism cages that allowed the separate collection of urine and faeces. Sizes of the metabolism cages were 1.2×0.6 m (length×width) and were made of steel with wooden slats. The 21-day experimental period consisted of a 12-day adaptation period to allow the pigs to become accustomed to the cages and to the new diet and a 9-day period during which urine and faeces were collected. The average ambient temperature was about

27℃ and the average humidity was about 72%.

Table 1. Ingredient composition of the experimental diets (g/kg diet)

Ingredients (as fed basis)	Diets			
	Tapioca	Coconut expeller	Rice bran	Beer by-product
Rice	231.5	231.5	231.5	231.5
Tapioca	509.5	370.0	340.0	353.0
Cane molasses	25.0	25.0	25.0	25.0
Groundnut extracted	125.0	100.0	125.0	100.0
Fish meal	78.0	35.0	48.0	25.0
Coconut expeller		200.0		
Rice bran			200.0	
Beer by-product				200.0
Chalk	11.5	11.5	11.5	11.5
$CaHPO_4$	4.0	4.0	4.0	4.0
$KHCO_3$	2.5		2.0	7.0
Salt	3.0	3.0	3.0	3.0
Premix[a]	10.0	10.0	10.0	10.0

[a] The vitamin and mineral premix supplied per 1 kg feed: 9000 IU vitamin A, 1800 IU vitamin D_3, 40 mg vitamin E, 3 mg vitamin K, 5 mg riboflavin, 50 mg ascorbic acid, 12 mg d-pantothenic acid, 30 mg niacin amide, 350 mg choline-chloride, 40 mg vitamin B_{12}, 1 mg folic acid, 0.1 mg biotin, 0.5 mg Co, 0.06 mg Se, 0.4 mg J, 80 mg Fe, 25 mg Cu, 44 mg MnO_2, 73 mg Zn, 20 mg Tylosin.

Diets and feeding

The ingredient compositions of the experimental diets are given in table 1. The control diet was composed with rice and tapioca as basal energy sources. In the other three diets, tapioca was partly exchanged with the same amount (200 g/kg diet) of coconut expeller, rice bran or beer by-product. Thus, the diets were similar, except for the contents of NSP-rich by-products and tapioca. The diet based on beer by-product had the highest NSP content (20.04%), followed by the diets based on rice bran (13.97%), coconut expeller (13.65%) and the tapioca (6.82%) respectively (table 2). The diet based on beer by-product contained the highest fermentable fractions (cellulose and hemicellulose) of NSP and the diet based on coconut expeller contained the highest lignin content.

The pigs were fed 2.5 times the energy required for maintenance, which was assumed to be 294 kg net energy per kg of metabolic weight $BW^{0.75}$ (ARC, 1981). The ration was increased each day based on an estimated weight gain of 600 g/day. Feed was mixed with water before feeding (2 l/kg feed) and provided in two equal meals per day. Water was given *ad libitum* through a drinking nipple at the front of each metabolism cage.

Measurements

To avoid disturbing the animals during the 9-day collection period, pigs were weighed four days before and one day after this period, before the morning feeding. The urine and faeces from each pig were collected separately and weighed twice daily.

Table 2. Chemical composition of experimental diets

Composition (as fed basis)	Diets			
	Tipioca	Coconut expeller	Rice bran	Beer by-product
NE, kcal/kg	2312	2213	2318	2104
CP[a], %	12.78	13.89	12.59	12.17
Crude fat[a], %	2.49	4.39	4.47	3.07
NSP[a,b], %	6.82	13.65	13.97	20.04
Cellulose[a], %	2.53	2.20	3.33	5.26
Hemicellulose, %	0.86	0.66	1.94	6.13
NDF[a], %	4.17	3.36	5.98	12.32
ADF[a], %	3.31	2.70	4.04	6.19
ADL[a], %	0.67	1.69	1.08	1.31
Water[a], %	13.89	13.12	13.68	12.30
Crude ash[a], %	5.06	7.31	5.59	4.92
Starch and sugar[a], %	58.96	47.64	49.70	47.50
Lysine, %	0.70	0.53	0.67	0.68
Methionine, %	0.27	0.24	0.25	0.24
Phosphorus, %	0.44	0.43	0.66	0.37
Sodium, %	0.21	0.17	0.18	0.16
Calcium, %	0.93	0.78	1.25	0.78
Potassium, %	0.83	0.97	0.87	0.82
Chloride, %	0.40	0.44	0.35	0.30
Magnesium	0.13	0.17	0.27	0.12
Copper, ppm	3.70	3.60	3.10	3.30
dEB[c], meq/100 g	19.20	19.93	19.93	19.65

[a] Analysed.
[b] Non-starch polysaccharides, determined as organic matter-(crude protein+crude lipid+starch+sugar).
[c] Dietary electrolyte balance (calculated as meq Na+K-Cl).

Urine was collected in a closed bucket (covered by lid with a central hole) via a funnel under the cage. Faeces were collected in a plastic bag (15 cm × 30 cm) using the velcro® support system (Van Kleef et al., 1994). A piece of glasswool was placed in the funnel and a piece of fine-meshed gauze was placed over the urine bucket, to trap particulate. The urine buckets and faeces bags were replaced twice a day. The urine funnels were changed every morning and the amount of urine remaining in the glasswool was determined by weighing the glasswool. The urine and faeces collected in the first 4 days were used for determining the nitrogen balance. They were stored at -20℃ until the nitrogen analyses were performed. To prevent nitrogen being lost by ammonia volatilisation during this period, urine was collected in 50 ml of 25% sulphuric acid to keep the pH below pH 2. The urine and faeces collected during the last 5 days, without adding acid to the urine, were used to make slurry. Urine and faeces were collected twice a day, their pH was measured directly after the collection, and they were then mixed to slurry in a plastic bucket with a surface area of 0.3 m^2. The buckets were stored uncovered in a room at ambient temperature (average about 27℃). After the collection period the pooled slurry was sampled for chemical analyses. The buckets were kept for a further 30 days in the same room. After this storage period, the slurry was mixed and sampled for chemical analysis.

The slurry was weighed at the beginning and the end of the storage period. The differences in total nitrogen of slurry at the start and the end of this 30-day storage period were used to calculate the nitrogen losses from the slurry.

Chemical analysis

All samples were analysed in duplicate. The diets and excreta were analysed for DM, ash, crude fibre, crude fat and total N according to AOAC (1990). NH_4^+-N content was determined titrimetrically and urinary urea was determined by kinetic UV test according to Neumann and Ziegenhorn (1977). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed as described by Huisman (1990). The pH was measured at room temperature with a Sentron instrument glass electrode (model 1001) directly submerged in the urine, in diluted faeces (mixed with distilled water in a ratio 1:4) and in the slurry.

Statistical analysis

The individual pig was the experimental unit. Effect of the diet on average daily gain, nitrogen intake, nitrogen retention, nitrogen excretion, and apparent faecal nitrogen digestibility, and on excreta compositions and nitrogen losses were analysed by one-way ANOVA using the GENSTAT statistical package (Genstat 5 Committee, 1993). When an F-test showed a significant effect of diet ($p<0.05$), means were separated with the LSD procedure with a confidence level of 0.05 (Genstat 5 Committee, 1993).

RESULTS

Nitrogen intake and nitrogen excretion

No health problems occurred during the experimental period, and no feed refusals were observed. Table 3 shows the animal daily BW gain, nitrogen intake, nitrogen excretion, nitrogen retention and apparent faecal nitrogen digestibility of the pigs on the different diets. Diet did not affect daily gain ($p>0.05$). Daily nitrogen intake from pigs fed the coconut expeller and beer by-product based diets was higher than from pigs on the other two diets ($p<0.05$). Total nitrogen excretion was higher in the coconut expeller based diet than in the beer by-product based diet ($p<0.05$). The nitrogen excretion pattern, which is indicated by the ratio of urinary nitrogen to faeces nitrogen, differed considerably between diets ($p<0.001$). The pigs fed the beer by-product diets excreted more nitrogen in faeces and less nitrogen in urine ($p<0.001$). Faecal nitrogen was lowest in the tapioca-based diet. The urinary nitrogen excretion was highest in the coconut expeller based diet. As a result, apparent nitrogen digestibility was highest in pigs fed the tapioca and coconut expeller based diets and lowest in pigs fed the diet based on beer by-product ($p<0.001$). The pigs fed the beer by-product based diet retained more nitrogen than the pigs on the other diets ($p<0.01$).

Amount, pH and composition of urine and faeces

The chemical composition of urine and faeces from pigs fed the different diets is shown in table 4. The amount of faeces and urine differed significantly between diets ($p<0.01$). The pigs fed the beer by-product based diet produced more faeces and less urine than the pigs on the other diets. No differences in faecal and urinary amounts were found between the other three diets. The diet had a profound effect on urinary urea concentration ($p<0.001$). The total amount and the concentration of urinary urea was highest in the pigs fed the coconut expeller and tapioca based diets ($p<0.001$), followed by the rice bran based diet. The pigs fed the beer by-product based diet excreted 23 to 42% less urea in urine than the pigs on the other three diets. On average, the pH of faeces from pigs fed the beer by-product

Table 3. Weight gain, nitrogen intake, excretion, apparent nitrogen digestibility and retention of pig fed different diets

Variables	Diets					
	Tapioca	Coconut expeller	Rice bran	Beer by-product	P[a]	SEM
Number of animals	4	4	4	4		
Initial BW, kg[b]	68.4	67.6	67.6	67.7	NS	1.51
Final BW, kg[c]	76.9	77.1	76.9	77.0	NS	2.43
Weight gain, g/day[d]	607	679	631	661	NS	41
N intake, g/day	37.1[e]	40.9[f]	35.5[e]	41.6[f]	*	1.1
Faecal N, g/day	4.42[e]	5.06[f]	5.52[f]	8.03[g]	***	0.17
Urinary N, g/day	18.4[e]	20.2[f]	15.8[g]	11.7[h]	***	0.39
Tot. N excretion, g/day	22.8[eg]	25.3[e]	21.3[eg]	19.7[fg]	*	1.45
Urinary N:faecal N	4.16[e]	4.00[e]	2.86[f]	1.46[g]	***	0.14
Apparent N digestibility, %	88.1[e]	87.6[e]	84.5[f]	80.7[g]	***	0.81
N retention, % of intake	38.5[e]	38.1[e]	40.0[e]	52.6[f]	**	2.4

[a] Probability of a significant treatment effect. * $p<0.05$; ** $p<0.01$; *** $p<0.001$; NS=not-significant.

[b] The pigs were weighed four d before the collection period.

[c] The pigs were weighed one d after the collection period.

[d] Calculated for a period of 14 d between the initial BW and the final BW.

[e,f,g,h] Different letters in superscript indicate significant difference ($p<0.05$).

Table 4. Amount and composition of faeces and urine from pigs fed different diets

Components	Diets					
	Tapioca	Coconut expeller	Rice bran	Beer by-product	P[a]	SEM
DM, g/kg						
Faeces	392[b]	458[c]	408[b]	350[d]	**	11.1
NH_4-N, g/kg						
Faeces	0.53[b]	0.62[c]	0.57[b]	0.54[b]	**	0.02
Urine	0.32[b]	0.23[c]	0.31[b]	0.34[b]	***	0.01
Total N, g/kg						
Faeces	8.87[b]	10.43[c]	10.43[c]	9.54[bc]	***	0.47
Urine	4.83[b]	5.28[c]	4.18[d]	3.75[e]	***	0.11
Faecal ash, g/kg	104.5[b]	134.1[c]	106.3[b]	68.4[d]	***	6.67
Faecal CF, g/kg	67.6[bc]	76.6[bc]	77.5[c]	62.6[dc]	**	2.95
Urin. urea, mmol/l	142.4[bd]	162.3[b]	122.8[cd]	115.7[c]	***	8.61
Tot. urinary urea, mmol/day	542[b]	619[c]	464[d]	357[e]	***	13.3
pH						
Faeces	8.00[b]	7.74[d]	7.96[b]	7.21[e]	**	0.15
Urine	7.52[b]	7.90[c]	7.63[b]	7.48[b]	*	0.08
Amount, g/d						
Faces	498[b]	485[b]	529[b]	842[c]	**	21.5
Urine	3806[b]	3815[b]	3780[b]	3086[c]	**	175

[a] Probability of a significant treatment effect. * p<0.05; ** p<0.01; *** p<0.001; NS=not-significant.
[b,c,d,e] Different letters in superscript indicate significant difference (p<0.05).

based diet was about 0.69 units lower than the pH of faeces from pigs fed the other three diets (p<0.01). The pH of urine from pigs fed the coconut expeller based diet was highest. No significant difference in urinary pH was found between the other three diets.

Nitrogen losses from slurry during storage

Diet did not affect amount of slurry (p>0.05). However, slurry DM was significantly influenced by the diet (p<0.001). The DM concentrations of slurry increased considerably during storage, because of water evaporation. They were highest for the beer by-product based diet and lowest for the tapioca based diet (table 5). Diets did not influence the total nitrogen concentration of the slurry at day 1 (p>0.05). However, on day 30 total nitrogen concentration was lower on the tapioca and coconut expeller based diets than the other two diets (p<0.01). On day 1, the pH of slurry from pigs fed the tapioca, the coconut expeller and the rice bran based diets was not different. The pH of slurry from pigs fed the beer by-product based diet was approximately 0.7 to 0.9 unit lower than the other three diets (p<0.001). The pH of the slurry fell slightly during the storage period but differences between diets followed the same pattern of those observed on day 1. Total nitrogen losses from slurry during the 30-day storage period was remarkably different between diets. Nitrogen losses for the beer by-product, rice bran, coconut

Table 5. Composition of slurry at d 1 and d 30 and N losses from slurry during storage

Components	Diets					
	Tapioca	Coconut expeller	Rice bran	Beer by-product	P[a]	SEM
Day 1						
Amount[b], kg	20.52	20.50	19.49	18.54	NS	2.01
DM, g/kg	74.53[d]	78.05[d]	81.51[d]	99.37[e]	***	2.27
Total N, g/kg	5.24	5.54	5.25	5.01	NS	0.28
pH	8.07[d]	7.88[d]	8.01[d]	7.19[e]	***	0.12
Day 30						
Amount, kg	14.37	14.09	13.12	12.87	NS	1.27
DM, g/kg	104.43[d]	109.78[dc]	118.06[e]	140.90[f]	***	3.12
Total N, g/kg	6.34[d]	6.04[d]	7.16[e]	6.87[e]	**	0.17
pH	7.89[d]	7.77[d]	7.83[d]	7.17[e]	***	0.09
N losses (%)[c]	15.30[d]	13.84[d]	8.13[e]	5.39[f]	***	1.11

[a] Probability of a significant treatment effect. * p<0.05; ** p<0.01; *** p<0.001; NS=not-significant.
[b] Amount of 5 collection days.
[c] Calculated by comparing the total N of slurry between day 30 and day 1.
[d,e,f] Different letters in superscript indicate significant difference (p<0.05).

expeller and tapioca based diets were 5.39, 8.13, 13.84 and 15.30%. respectively. Nitrogen Losses from slurry of pigs fed the beer by-product based diets were 34 to 65% lower than for the other three diets.

DISCUSSION

The main objective of this study was to evaluate the possibility to lower the pH of slurry and to lower urinary nitrogen excretion and nitrogen losses from slurry during storage by increasing the level of dietary NSP from NSP-rich by-products.

Nitrogen excretion

In the present study the diets had a similar NE content but were formulated from different by-products and differed mainly in NSP content. The results from this exeriment support the concept that the amount of NSP in the diet can influence the nitrogen excretion pattern in pigs. Increasing the amount of NSP in the diet shifts nitrogen excretion via urine to faeces. The largest effect was obtained from the diet based on beer by-product. This diet contained the highest amount of NSP and fermentable fractions of NSP in the diet, compared with the other three diets. The difference in nitrogen excretion pattern in this study is in agreement with our previous observations (Canh et al., 1996 and 1997) and with the findings of other researchers (Mroz et al., 1993. Schulze et al., 1993) who found that the total amount of NSP as well as contents of cellulose and hemicellulose were related positively to faecal nitrogen excretion and negatively to the urinary nitrogen excretion. Fermentable carbohydrates serve as an energy source for microflora in the large intestine of pigs, and urea secreted from the blood into the large intestine (Low, 1985) serves as a nitrogen source. A high-energy supply of fermentable organic matter to the microbes of the large intestine induces a high secretion of urea from the blood (Low, 1985) and a high microbial growth. When urea is transferred to the lumen of the large intestine, it is broken down to ammonia by bacterial urease and then used for microbial protein synthesis. This protein is finally excreted in the faeces (Canh et al., 1997). The amount of urea secreted from blood into the large intestine increases with increased dietary fibre content (Low, 1985), resulting in a reduced urea content in the portal plasma (Malmlöf, 1985). The synthesis of microbial protein causes less ammonia to be reabsorbed from the colon. As a result nitrogen excretion shifts from urine to faeces.

When comparing the diets with respect to their nitrogen balance it is shown from table 3 that nitrogen retention is highest for the beer by-product diet. The other diets gave similar nitrogen retention. The diet with coconut expeller had a relatively low lysine content. This might have affected nitrogen retention to some extent, although this retention was similar to two of the other three diets. For the two diets with similar contents of NSP, urinary nitrogen excretion from pigs fed the coconut expeller based diet was higher than observed from the pigs fed the rice bran based diet. This difference might be caused by the higher intake of nitrogen by pigs fed the coconut expeller. The high lignin content of the diet might also depress microbial activities and reduce the degradation of fibre in the large intestine of pigs (Canh et al., 1997).

Nitrogen loss from slurry during storage

The results from this experiment support our recent studies (Canh et al., 1996 and 1997) which have shown that fermentable carbohydrates in the diet can influence the ammonia volatilisation from pig slurry during storage. In the present study, the level of NSP in the diets ranged from 6.82 to 20.04%. It was observed that the total nitrogen losses from the slurry during the 30-day storage were lower for the NSP-rich diets. In this experiment, the slurry was stored in plastic containers. Nitrogen losses from the slurry only occurred by ammonia volatilisation from the surface of the slurry. According to Muck and Steenhuis (1981) the main part of ammonia emission originates from urea in the urine. Urea is converted into ammonia and carbon dioxide by urease present in faeces. The conversion starts as soon as the urine comes into contact with faeces. In the slurry, the equilibrium vapour pressure of ammonia is controlled by the total concentration of ammoniacal nitrogen and the pH of slurry. In the present study, two main reasons for the lower volatilisation of ammonia from slurry of pigs fed the NSP-rich diets can be hypothesised. Firstly, increasing the amount of NSP in the diet caused nitrogen excretion to shift from urine to faeces. This resulted in a reduction of urinary urea content, and consequently, reduced the ammonium content of slurry (Schulze et al., 1993; Canh et al., 1997). Secondly, The pH of slurry was lowered when more NSP was included in the diet. According to Sommer and Husted (1995), the slurry pH is very important for the government of ammonia volatilisation from pig slurry. In our previous studies (Canh et al., 1996 and 1997) we found that the pH of the slurry was strongly influenced by the ammonium and VFA concentrations of the slurry. In pigs, VFA are mainly produced from dietary NSP by anaerobic microbial fermentation in the large intestine (Imoto and Namioca, 1978; Canh et al., 1997) and in the slurry during storage (Spoelstra, 1979; Canh et al., 1996 and 1997). In this study, VFA formation and the reduction of slurry ammonia probably caused the low pH of slurry from pigs fed NSP-rich diets. A lower ammonium concentration and a lower pH of slurry reduced the losses of nitrogen through evaporation.

CONCLUSION

Including non-starch polysaccharides rich by-products in the diet of pigs shifts nitrogen excretion from the volatilisable form in urine to the less accessible protein form in the faeces. Non-starch polysaccharides also

lower the pH of slurry, consequently there are clearly reduced nitrogen losses from slurry during storage. Such an approach may be an economical way of improving the quality of fertiliser from pig farming and of reducing the environmental impact of pig production.

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