Performance of Growing-finishing Pigs Fed Diets Containing Graded Levels of Biotite, an Alumninosilicate Clay

P. A. Thacker*

Department of Animal Science, University of Saskatchewan, 51 Campus Drive, Saskatoon Saskatchewan, S7N 5A8, Canada

ABSTRACT : The objective of this study was to evaluate the potential of an alumninosilicate clay, marketed under the trade name Biotite V, to improve growing-finishing pig performance and to determine its effects on nutrient digestibility and excretion. Sixty crossbred pigs (22.3±2.7 kg, Camborough 15 Line female×Canabred sire) were assigned on the basis of sex, weight and litter to one of four dietary treatments in a 2×4 (two sexes and four treatments) factorial design experiment. The experimental diets were based on barley and soybean meal and contained 0, 0.25, 0.5 or 0.75% biotite during the growing period (22.3-60.5 kg) and 0, 0.5, 1.0 or 1.5% biotite during the finishing period (60.5-110.3 kg). Each pig was allowed access to its own individual feeder for 30 min twice daily (07:00 and 15:00 h). Individual pig body weight, feed consumption and feed conversion were recorded weekly. The pigs were slaughtered at a commercial abattoir when they reached an average weight of 110.3 kg. Carcass weight was recorded and dressing percentage calculated. Carcass fat and lean measurements were obtained with a Destron PG 100 probe between the 3rd and 4th last ribs, 70 mm of the midline. Total tract digestibility coefficients for dry matter, energy, nitrogen and phosphorus were determined using three males and three females per treatment starting at an average weight of 52.2±3.8 kg. These pigs were housed under identical conditions as those used in the growing stage and were fed the same diets modified only by the addition of 0.5% chromic oxide as a digestibility marker. Over the entire experimental period (22.3-110.3 kg), daily gain was unaffected ($p>0.05$) by the inclusion of biotite in the diet. There was a cubic response for feed intake ($p=0.06$) and a quadratic response ($p=0.07$) for feed conversion due to biotite. Feeding biotite produced no significant ($p>0.05$) linear or quadratic effects on any of the carcass traits measured. Dry matter digestibility decreased linearly ($p=0.02$) with increasing levels of biotite in the diet. However, digestibility coefficients for energy, nitrogen and phosphorus were unaffected ($p<0.05$) by biotite inclusion. *Lactobacilli* and enterobacteria numbers were unaffected by inclusion of biotite while Salmonella was not detected in any of the fecal samples. The overall results of this experiment indicate that biotite inclusion did not reduce fecal excretion of nitrogen or phosphorus and failed to improve nutrient digestibility. Neither growth rate nor carcass quality was improved while a modest improvement in feed conversion was observed at lower levels of inclusion. Based on the results of this experiment, it would be difficult to justify the routine inclusion of biotite in diets fed to grower-finisher pigs. Whether or not a greater response would have been obtained with pigs of a lower health status is unknown. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 11 : 1666-1672)***

Key Words : Growing Pigs, Digestibility, Carcass Traits, Bacterial Counts, Biotite

INTRODUCTION

Pollution from intensive livestock operations is becoming a serious problem in many areas of the world (Kornegay and Verstegen, 2001). In some countries, this has led to the introduction of legislation to reduce nutrient excretion by farm animals, in order to minimize their potential to contribute towards environmental pollution. Therefore, in the future, when formulating swine diets, the goal will no longer be solely to maximize pig performance because greater attention will have to be paid to minimizing nutrient excretion and avoiding the production of noxious odours (Kornegay and Verstegen, 2001).

The development of methods to reduce the extent of environmental pollution from swine production units has been the subject of several recent reviews (Kornegay and Verstegen, 2001; Paik, 2001; Han et al., 2001). Promising techniques include the choice of highly digestible ingredients, proper feed processing, phase feeding, split-sex feeding, reduction of feed wastage, as well as dietary inclusion of various feed additives.

One group of feed additives that has been studied to determine their potential to reduce nutrient excretion by swine are the hydrous silicate clays including clinoptilolite, zeolite and bentonite (Shurson et al., 1984; Pearson et al., 1985; Castro and Mas, 1989). These compounds are crystalline, hydrated alumninosilicate molecules composed of alkali and alkaline earth cations along with small amounts of various other elements. The molecules in these clays are arranged in three-dimensional structures creating internal voids and channels capable of trapping certain molecules including ammonia (Mumpton and Fishman, 1977).

Recently, a new Bio-Ceramic powder, marketed under the name of Biotite V, was developed in Korea. It is suggested that this product reduces nitrogen and phosphorus excretion and improves pig performance. The objective of

* Corresponding Author: P. A. Thacker. Tel: +1-306- 966-4159, Fax: +1-306-966-4151, E-mail: thacker@admin.usask.ca

Received March 25, 2003; Accepted August 18, 2003

Table 1. Formulation and chemical composition of grower pig (22.3-60.5 kg) diets containing graded levels of biotite

	Level of biotite in diet (%)			
	0.00	0.25	0.50	0.75
Diet formulation (% as fed)				
Barley (12.1% CP)	72.02	71.77	71.52	71.27
Soybean meal (46.5% CP)	18.80	18.80	18.80	18.80
Tallow	5.45	5.45	5.45	5.45
Limestone	0.74	0.74	0.74	0.74
Dicalcium phosphate	1.49	1.49	1.49	1.49
Salt	0.50	0.50	0.50	0.50
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00
Biotite	0.00	0.25	0.50	0.75
Chemical composition (% as fed)				
Moisture	9.95	9.38	9.06	9.10
Crude protein	17.46	17.44	17.21	17.54
Ash	5.03	5.17	5.40	5.69
Ether extract	6.88	6.87	6.83	8.00
Acid detergent fibre	5.96	6.52	7.19	7.18
Calcium	0.62	0.65	0.64	0.64
Phosphorus	0.60	0.64	0.64	0.63

[1] Supplied per kilogram of diet: 8,250 IU, vitamin A; 825 IU, vitamin D_3; 40 IU, vitamin E; 4 mg vitamin. K; 1 mg thiamine; 5 mg riboflavin; 35 mg niacin; 15 mg pantothenic acid; 2 mg folic acid; 12.5 μg vitamin B_{12}; 0.2 mg biotin; 80 mg iron; 25 mg manganese; 100 mg zinc; 50 mg Cu; 0.5 mg I; 0.1 mg selenium.

Table 2. Formulation and chemical composition of finisher pig (60.5-110.3 kg) diets containing graded levels of biotite

	Level of biotite in diet (%)			
	0.00	0.50	1.00	1.50
Diet formulation (% as fed)				
Barley (12.1% CP)	79.90	78.84	77.80	76.75
Soybean meal (46.5% CP)	12.80	13.07	13.32	13.58
Tallow	3.23	3.52	3.80	4.09
Limestone	1.00	0.99	0.99	0.98
Dicalcium phosphate	1.57	1.58	1.59	1.60
Salt	0.50	0.50	0.50	0.50
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00
Biotite	0.00	0.50	1.00	1.50
Chemical composition (% as fed)				
Moisture	8.98	8.68	8.72	8.32
Crude protein	15.60	15.73	15.70	15.49
Ash	4.79	5.40	5.81	6.56
Ether extract	4.88	5.50	5.81	6.06
Acid detergent fibre	6.97	7.93	8.39	8.05
Calcium	0.64	0.75	0.74	0.79
Phosphorus	0.57	0.61	0.60	0.64

[1] Supplied per kilogram of diet: 8,250 IU, vitamin A; 825 IU, vitamin D_3; 40 IU, vitamin E; 4 mg. vitamin K; 1 mg thiamine; 5 mg riboflavin; 35 mg niacin; 15 mg pantothenic acid; 2 mg folic acid; 12.5 μg vitamin B_{12}; 0.2 mg biotin; 80 mg iron; 25 mg manganese; 100 mg zinc; 50 mg Cu; 0.5 mg I; 0.1 mg selenium.

this study was to evaluate the potential of biotite to improve growing-finishing pig performance and to determine its effects on nutrient digestibility and excretion.

MATERIALS AND METHODS

Acquisition and chemical composition of biotite

The biotite used in this experiment was provided by the Seobong BioBestech Company (Seoul, Korea). The product contained 71.2% SiO_2, 15.7% Al_2O_3, Fe_2O_3, 0.66% CaO, 2.05% MgO, 3.5% K_2O, and 2.01% Na_2O (Manufacturers specifications).

Growth trial

Sixty crossbred pigs (Camborough 15 Line female× Canabred sire, Pig Improvement Canada Ltd., Acme Alberta), weighing an average of 22.3±2.7 kg, were assigned on the basis of sex, weight and litter to one of four dietary treatments. The experimental diets (Table 1 and 2) were based on barley and soybean meal and contained 0, 0.25, 0.5 or 0.75% biotite during the growing period (22.3-60.5 kg) and 0, 0.5, 1.0 or 1.5% biotite during the finishing period (60.5-110.3 kg). The diets were formulated to supply 17.5% crude protein during the grower phase (22.3-60.5 kg) and 15.5% crude protein during the finisher phase (60.5-110.3 kg). All diets contained sufficient amino acids, vitamins and minerals to meet or exceed the levels recommended by the National Research Council (1998) for pigs with a lean growth potential of 325 g/day. The diets were pelleted using low-pressure steam at approximately 60°C.

The pigs were housed in groups of four in 2.7×3.6 m concrete floored pens and were provided water *ad libitum*. The pens were equipped with four individual feeders. Each pig was allowed access to its own individual feeder for 30-min twice daily (07:00 and 15:00 h). Individual body weight, feed consumption and feed conversion were recorded weekly. Pigs were assigned to feeders in such a way as to minimize the potential for treatment effects to be confounded with environmental effects. The duration of the growth trial averaged 96 days.

Digestibility determination

Total tract digestibility coefficients for dry matter, energy, nitrogen and phosphorus were determined using three males and three females per treatment starting at an average weight of 52.2±3.8 kg. These pigs were housed under identical conditions as those used in the growth trial and were fed the same diets as those used during the growing stage modified only by the addition of 0.5% chromic oxide as a digestibility marker (Table 3). The marked feed was provided for a seven-day acclimatization period, followed by a three-day fecal collection. Fecal collections were made by bringing animals into a clean room immediately after feeding and recovering freshly voided feces. The fecal samples were frozen for storage. Prior to analysis, the samples were dried in a forced air oven dryer at 66°C for 60 h, followed by fine grinding (0.5 mm screen).

Table 3. Formulation and chemical composition of diets containing graded levels of Biotite used to determine nutrient digestibility for pigs (52.2 kg)

	Level of biotite in diet (%)			
	0.00	0.25	0.50	0.75
Diet formulation (% as fed)				
Barley (12.1% CP)	71.66	71.41	71.16	70.91
Soybean meal (46.5% CP)	18.70	18.70	18.70	18.70
Tallow	5.42	5.42	5.42	5.42
Limestone	0.74	0.74	0.74	0.74
Dicalcium phosphate	1.48	1.48	1.48	1.48
Salt	0.50	0.50	0.50	0.50
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00
Chromic oxide	0.50	0.50	0.50	0.50
Biotite	0.00	0.25	0.50	0.75
Chemical composition (% as fed)				
Moisture	8.69	8.68	8.48	8.64
Crude protein	17.48	17.31	17.54	17.34
Phosphorous	0.66	0.71	0.69	0.70
Chromic oxide	0.48	0.50	0.47	0.49
Gross energy (kcal/kg)	4,252	4,233	4,215	4,227
Digestible energy (kcal/kg)	3,326	3,258	3,265	3,256

[1] Supplied per kilogram of diet: 8,250 IU. vitamin A; 825 IU, vitamin D_3; 40 IU. vitamin E; 4 mg vitamin K; 1 mg thiamine; 5 mg riboflavin; 35 mg niacin; 15 mg pantothenic acid: 2 mg folic acid: 12.5 μg. vitamin B_{12}; 0.2 mg biotin: 80 mg iron: 25 mg manganese; 100 mg zinc; 50 mg Cu: 0.5 mg I: 0.1 mg selenium.

Carcass measurements

Pigs were slaughtered at a commercial abattoir when they reached an average weight of 110.3 kg. Carcass weight was recorded and dressing percentage calculated. Carcass fat and lean measurements were obtained with a Destron PG 100 probe between the 3rd and 4th last ribs, 70 mm of the midline. These values were then used in calculating Carcass Value Indices according to the table of differentials in effect at the time of the experiment (Saskatchewan Pork International. 2000).

Chemical analysis

Samples of the growing and finishing rations were analysed for moisture, crude protein (nitrogen). ash, ether extract. acid detergent fibre. calcium and phosphorus according to the methods of the Association of Official Analytical Chemists (1990). For digestibility determinations. samples of feed and feces were analysed for moisture, crude protein and phosphorus according to the methods of the Association of Official Analytical Chemists (1990). An adiabatic oxygen bomb calorimeter (Parr; Moline, Illinois) was used to determine gross energy content of feed and feces. Chromic oxide was determined by the method of Fenton and Fenton (1979).

Measurement of fecal bacteria

Fresh fecal samples from each pen were placed into pre-weighed 15 ml sterile tubes containing 0.5% cysteine hydrochloride. The samples were kept on ice and processed within 3 h of collection. The samples were diluted in peptone water and diluted either 10^{-2} or 10^{-4}. Dilutions were then applied to sterile media using an automated plater (Autoplate. Spiral Biotech Inc., Bethesda. MD. USA).

The selective media and the bacterial species enumerated were MacConkey Agar for Enterobacteria (i.e., *E. coli*). Brilliant Green Agar for Salmonella and deMan Rogosa and Sharpe Agar for Lactobacilli. Salmonella and Enterobacteria were incubated aerobically at 37°C for 20 h. Lactobaccilli were incubated anerobically at 37°C (Gas-Pak anerobic system, Becton Dikinson Microbiology Systems) for 20 h. Counts were made and recorded as Colony Forming Units (CFU) per gram of feces.

Statistical analysis

Pig performance. digestibility and carcass data were analyzed as a 4×2 factorial using the General Linear Models procedure of the Statistical Analysis System Institute. Inc. (SAS 1990) with the factors in the model consisting of ration, sex and their interaction. Bacterial counts were analyzed as a one- way ANOVA. The significance of linear. quadratic and cubic effects was also tested.

RESULTS

The health status of the pigs on the growth trial was excellent throughout the experimental period and only two pigs failed to complete the experiment. There was only one mortality during the experiment and this occurred in treatment 3 (0.5% biotite in the grower phase and 1.0% biotite in the finisher phase). This pig showed evidence of lameness (splay leg) for approximately two weeks prior to its death. Post-mortem examination at the veterinary college

Table 4. Performance of male and female pigs (22.3-110.3 kg) fed diets containing graded levels of biotite

	Level of biotite (%)				SEM[1]	Sex		SEM[1]	P values for contrasts		
Grower diet	0.00	0.25	0.50	0.75		Males	Females		Linear	Quadratic	Cubic
Finisher diet	0.00	0.50	1.00	1.50							
Growing period (22.3-60.5 kg)											
Daily gain (kg)	0.79	0.83	0.79	0.78	0.025	0.84[a]	0.76[b]	0.018	0.66	0.14	0.28
Daily intake (kg)	1.74	1.73	1.64	1.69	0.051	1.80[a]	1.59[b]	0.036	0.40	0.91	0.29
Feed conversion	2.22	2.08	2.07	2.17	0.025	2.15	2.11	0.019	0.35	0.01	0.97
Finishing period (60.5-110.3 kg)											
Daily gain (kg)	1.07	1.09	1.03	1.08	0.034	1.13[a]	1.00[b]	0.024	0.93	0.92	0.30
Daily intake (kg)	3.17	3.20	2.97	3.16	0.078	3.35[a]	2.88[b]	0.055	0.66	0.67	0.04
Feed conversion	2.96	2.97	2.88	2.94	0.069	2.98	2.88	0.049	0.74	0.86	0.36
Overall experiment (22.3-110.3 kg)											
Daily gain (kg)	0.93	0.95	0.91	0.92	0.021	0.97[a]	0.88[b]	0.015	0.73	0.44	0.20
Daily intake (kg)	2.44	2.41	2.20	2.40	0.070	2.51[a]	2.20[b]	0.050	0.47	0.30	0.06
Feed conversion	2.63	2.54	2.40	2.60	0.072	2.58	2.50	0.051	0.61	0.07	0.25

[1] Standard error of the mean. [a, b] Indicates significance at p=0.05.

Table 5. Carcass composition for male and female pigs fed diets containing graded levels of biotite

	Level of biotite (%)				SEM	Sex		SEM[1]	P values for contrasts		
Grower diet	0.00	0.25	0.50	0.75		Males	Females		Linear	Quadratic	Cubic
Finisher diet	0.00	0.50	1.00	1.50							
Carcass trait											
Live weight (kg)	111.5	110.6	109.4	109.9	1.24	112.2[a]	108.6[b]	0.88	0.32	0.81	0.59
Carcass weight (kg)	88.0	87.8	87.1	85.5	1.43	87.3	87.1	1.01	0.17	0.61	0.98
Dressing percentage	79.1	79.5	79.6	77.8	1.26	77.8[d]	80.4[c]	0.89	0.44	0.52	0.77
Carcass value index	112.3	110.7	112.7	110.1	1.12	110.4	112.3	0.80	0.29	0.93	0.20
Lean yield (%)	60.0	59.6	61.6	59.5	0.51	59.6[a]	60.7[b]	0.36	0.96	0.25	0.01
Loin fat (mm)	19.3	20.2	16.3	20.7	1.21	20.3[d]	18.02[c]	0.86	0.82	0.29	0.03
Loin lean (mm)	55.9	53.1	57.5	56.2	1.83	55.6	55.8	1.29	0.63	0.65	0.27

[1] Standard error of the mean. [a, b] Indicates significance at p=0.05 while [c, d] indicates significance at p=0.10.

indicated that the cause of death was neoplastic infiltration of the spinal cord. A second pig in treatment 4 (0.75% biotite in the grower phase and 1.5% biotite in the finisher phase) appeared to suffer from a twisted gut and performed poorly during the experimental period. It became evident that this pig was not going to reach market weight and therefore it was removed from the experiment and all data attributed to it was deleted from the data file.

During the grower phase (22.3-60.5 kg), there were no significant (p>0.05) effects of biotite inclusion on weight gain or feed intake (Table 4). However, there was a significant (p=0.01) quadratic effect from biotite inclusion on feed conversion with pigs fed the 0.25 and 0.50% biotite diets having improved feed conversion compared with pigs fed 0 or 0.75% biotite.

During the finishing phase (60.5-110.3 kg), there were no significant (p>0.05) linear or quadratic effects due to biotite inclusion for weight gain or feed conversion. However, feed intake showed a significant (p=0.04) cubic effect with biotite inclusion.

Over the entire experimental period (22.3-110.3 kg), daily gain was unaffected (p>0.05) by biotite. There was a cubic response for feed intake (p=0.06) and a quadratic response (p=0.07) for feed conversion due to biotite.

During the growing phase, the finishing phase and over the entire experimental period, castrate males consumed more feed (p=0.01) and gained weight more rapidly (p=0.01) than female pigs while feed conversion was unaffected by sex of pig (p>0.05).

The effects of biotite inclusion on carcass traits are shown in Table 5. Parameters measured included dressing percentage, carcass value index, lean yield as well as fat and lean thickness over the loin. There were no significant (p>0.05) linear or quadratic effects on any of these carcass traits as a result of biotite inclusion. There were significant cubic effects on lean yield (p=0.01) and loin fat (p=0.03) as a result of biotite inclusion but the biological importance of these differences is questionable. Castrate males had significantly lower dressing percentage (p=0.06) and lean yield (p=0.04) than females but had a higher loin fat thickness (p=0.07).

Excretion patterns and digestibility coefficients for dry matter, energy, nitrogen and phosphorus are shown in Table 6. Dry matter digestibility decreased linearly (p=0.02) with increasing levels of biotite in the diet. Digestibility coefficients for energy, nitrogen and phosphorus were unaffected (p>0.05) by biotite inclusion. Fecal excretion of nitrogen and phosphorus were also unaffected (p>0.05) by

Table 6. Excretion patterns and digestibility of nitrogen and phosphorus for pigs (52.2 kg) fed graded levels of biotite

	Level of biotite (%)				SEM[1]	Sex		SEM	P values for contrasts		
	0.00	0.25	0.50	0.75		Males	Females		Linear	Quadratic	Cubic
Dry matter											
Feed intake (g/d)	1,760.8	1,739.4	1,852.2	1,957.7	133.2	1,979.8^{a}	1,675.2^{b}	94.2	0.25	0.64	0.81
Fecal excretion (g/)	373.2	395.7	410.8	452.5	30.5	436.6	379.5	21.6	0.08	0.75	0.80
Dry matter digestibility (%)	78.7^{a}	77.3^{ab}	77.3^{ab}	76.8^{b}	0.46	77.9	77.3	0.32	0.02	0.64	0.13
Energy											
Energy intake (kcal/d)	8,203.5	8,070.9	8,520.1	9,044.6	616.4	9,164.2^{a}	7,755.3^{b}	435.8	0.29	0.60	0.85
Energy excretion (kcal/d)	1,776.2	1,858.6	1,918.2	2,071.8	143.9	2,036.8	1,776.6	101.8	0.16	0.80	0.85
Energy digestibility (%)	78.3	77.0	77.5	77.0	0.49	77.8	77.1	0.35	0.16	0.43	0.26
Nitrogen											
Nitrogen intake (g/d)	53.9	52.7	56.8	59.4	4.06	60.4^{a}	51.1^{b}	2.87	0.27	0.64	0.72
Nitrogen excretion (g/d)	11.6	11.6	12.2	12.8	0.87	12.9	11.2	0.62	0.29	0.74	0.90
Nitrogen digestibility (%)	78.4	77.9	78.5	78.3	0.56	78.5	78.0	0.39	0.89	0.75	0.46
Phosphorus											
Phosphorus intake (g/d)	12.9	13.6	14.1	15.1	1.02	15.0^{a}	12.7^{b}	0.72	0.13	0.89	0.88
Phosphorus excretion (g/d)	5.8	5.8	5.9	6.6	0.47	6.5^{a}	5.4^{b}	0.33	0.17	0.47	0.74
Phosphorus digestibility (%)	55.8	57.5	58.2	55.8	1.48	57.0	56.6	1.04	0.92	0.17	0.78

[1] Standard error of the mean.

Table 7. Bacteria counts for pigs fed diets containing graded levels of biotite

	Level of biotite (%)				SEM[1]	P values for contrasts		
Grower diet	0.00	0.25	0.50	0.75		Linear	Quadratic	Cubic
Finisher diet	0.00	0.50	1.00	1.50				
Bacteria								
Lactobacilli (CFU/g$\times 10^{9}$)	1.62	1.72	1.40	1.94	0.46	0.66	0.49	0.39
Lactobacilli (Log10 CFU/g)	9.17	9.20	8.65	9.26	0.26	0.72	0.13	0.04
Enterobacteria (CFU/g$\times 10^{9}$)	0.79	0.48	0.32	0.95	0.04	0.60	0.31	0.11
Enterobacteria (Log10 CFU/g)	6.90	6.68	6.50	6.97	0.32	0.78	0.61	0.16
Salmonella (CFU/g)	ND	ND	ND	ND	ND	ND	ND	ND

[1] Standard error of the mean. [2] ND=not detected.

treatment. Sex of pig had no significant ($p>0.05$) effects on any of the digestibility coefficients measured.

The effects of biotite inclusion on bacterial counts are presented in Table 7. The numbers of *Lactobacilli* (so called beneficial bacteria) and Enterobacteria (i.e. *E. coli*) were unaffected ($p>0.05$) by inclusion of biotite. Salmonella was not detected in any of the fecal samples.

DISCUSSION

The overall results of this experiment do not support the claim of the distributor (Seobong BioBestech Company, Seoul, Korea) that biotite increases weight gain of treated pigs. However, the significant quadratic response to biotite inclusion observed in the present experiment data does provide some support for the suggestion that inclusion of biotite in the diet may improve feed conversion, at least at lower levels of inclusion.

Previous experiments with alumninosilicate clays have generated conflicting responses on their effects on pig performance. Pearson et al. (1985) using 0.4% and 0.8% zeolite, Mathews et al. (1999) using 0.5% hydrated sodium calcium alumninosilicate and Shurson et al. (1984) using 0.3% zeolite or 0.5% clinoptilolite observed no significant improvements in pig performance. In contrast, Kwon et al. (2002a) observed significant improvements in weight gain, feed intake and feed conversion when pigs were fed 0.3% biotite. Similarly, Castro and Iglesias (1989) observed significant improvements in weight gain and feed conversion when pigs were fed 3.0 and 6.0% zeolite.

The discrepancy between experiments showing a positive response and those showing no effect may be partially explained by the health status of the pigs used in the various experiments. Pond et al. (1981) concluded that, in the absence of a diarrhoea problem, inclusion of clinoptilolite or zeolite was likely to be an ineffective means of improving pig performance.

None of the carcass traits measured in the current experiment were affected by biotite inclusion. Therefore, these findings do not support the claim of the distributor (Seobong BioBestech Company, Seoul, Korea) that feeding biotite to pigs reduces backfat thickness. It is difficult to conceive of a mechanism, other than through a simple reduction in energy intake, whereby dietary inclusion of biotite could reduce backfat thickness. If lower dietary energy levels were the potential mechanism producing the reduction in backfat, it would appear that higher levels of biotite inclusion than those used in the present experiment are necessary in order to affect the desired result.

The general failure of biotite inclusion to alter carcass traits is consistent with the results of Pearson et al. (1985) when feeding zeolite and Mathews et al. (1999), when feeding hydrated sodium, calcium alumninosilicate to growing-finishing pigs. In contrast, Taverner et al. (1984) reported higher backfat levels in pigs fed sodium bentonite while Ward et al. (1991) reported a leaner carcass in pigs fed sodium zeolite.

Dry matter digestibility decreased linearly with increasing levels of biotite in the diet. This finding supports the work of Castro and Mas (1989) with increased levels of zeolite, and Collings et al. (1980) and Taverner et al. (1984) with increased levels of sodium bentonite. In contrast, Kwon et al. (2002b) reported no effects on dry matter digestibility when they fed biotite to nursery pigs. Collings et al. (1980) reported a significantly reduced intestinal transit time with sodium bentonite inclusion. If a similar effect could be attributed to biotite, this could at least partially explain some of the observed decrease in dry matter digestibility.

Digestibility coefficients for nitrogen were unaffected by biotite inclusion. Similar results have been reported by Kwon et al. (2002b) when feeding biotite, Collings et al. (1980) with sodium bentonite, Shurson et al. (1984) and Castro and Mas (1989) when feeding zeolite and Shurson et al. (1984) with clinoptilolite. Phosphorus digestibility was similarly unaffected by biotite. The author is unaware of any previous reports on the effects of alumninosilicate clays on phosphorus digestibility.

Fecal excretion of nitrogen and phosphorus were unaffected by biotite inclusion in the present experiment. Therefore, these findings do not support the claim of the distributor (Seobong BioBestech Company, Seoul, Korea) that feeding biotite to pigs reduces nitrogen and phosphorus in feces.

The failure of biotite to alter intestinal bacterial counts supports the work of Pond et al. (1988) and Varel et al. (1987) who reported no effect of clinoptilolite on total colon counts or on ureolytic bacteria.

In conclusion, the results of this experiment indicate that biotite inclusion did not reduce fecal excretion of nitrogen or phosphorus and failed to improve nutrient digestibility. Neither growth rate nor carcass quality was improved by biotite feeding while a modest improvement in feed conversion was observed at lower levels of inclusion.

IMPLICATIONS

Under the conditions of the present experiment, no beneficial effects were observed on fecal excretion patterns of nitrogen and phosphorus, nutrient digestibility, growth rate, carcass traits, or bacterial counts as a result of biotite inclusion in the diet of growing-finishing pigs. Whether or not a greater response would have been obtained with pigs of a lower health status is unknown. Feed conversion was improved at lower levels of inclusion. Therefore, if biotite is too be included in grower-finisher diets, best results will be obtained by inclusion at a relatively low level (0.25%) and in diets fed to younger animals.

REFERENCES

AOAC. 1990. Official Methods of Analysis. 15th Edition. Association of Official Analytical Chemists, Washington, DC.

Castro, M. and M. Iglesias. 1989. Effect of zeolite on traditional diets for fattening pigs. Cuban J. Agric. Sci. 23:289-291.

Castro, M. and E. Mas. 1989. Effect of different levels of zeolite on the balance of some nutrients for pre-fattening pig feeds. Cuban J. Agric. Sci. 23:55-59.

Collings, G. F., S. A. Thomasson, P. K. Ku and E. R. Miller. 1980. Sodium bentonite in swine diets. J. Anim. Sci. 50:272-277.

Fenton, T. W. and M. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and faces. Can. J. Anim. Sci. 59:631-634.

Han, I. K., J. H. Lee, X. S. Piao and D. F. Li. 2001. Feeding and management system to reduce environmental pollution in swine production: A review. Asian-Aust. J. Anim. Sci. 14:432-444.

Kornegay, E. T. and M. W. A. Verstegen. 2001. Swine nutrition and environmental pollution and odor control. In: Swine Nutrition (Ed. A. J. Lewis and L. L. Southern). CRC Press, Baco Raton, FL. pp. 609-630.

Kwon, O. S., I. H. Kim, J. W. Hong, S. H. Lee and Y. K. Jung. 2002a. Evaluation of germanium biotite as a substitute for antibiotics in growing pig diets. J. Anim. Sci. 80 (Suppl. 1) 391 (Abstr).

Kwon, O. S., I. H. Kim, J. W. Hong, S. H. Lee and Y. K. Jung. 2002b. Effects of germanium biotite supplementation on the growth performance and serum characteristics in nursery pigs. J. Anim. Sci. 80 (Suppl. 1) 394 (Abstr).

Matthews, J. O., J. J. Southern and T. D. Bidner. 1999. Effect of a hydrated sodium calcium alumninosilicate on growth performance and carcass traits of pigs. Prof. Anim. Sci. 15:196-200.

Mumpton, F. and P. H. Fishman. 1977. The application of natural zeolites in animal science and aquaculture. J. Anim. Sci. 45:1188-1203.

National Research Council, National Academy of Sciences, 1998. Nutrient Requirements of Domestic Animals. No. 2. Nutrient Requirements of Swine. 10th Edition. NAS-NRC, Washington, DC.

Paik, I. K. 2001. Management of excretion of phosphorus, nitrogen and pharmacological level minerals to reduce environmental pollution from animal production: A review. Asian-Aust. J. Anim. Sci. 14:384-394.

Pearson, G., W. C. Smith and J. M. Fox. 1985. Influence of dietary zeolite on pig performance over the weight range 25-87 kg. New Zealand J. Exp. Agric. 13:151-154.

Pond, W. G., J. T. Yen, R. N. Lindvall and R. R. Maurer. 1981. Effect of pig breed group and of soil or clinoptilolite (a zeolite) in the pen environment on preweaning weight gain and survival. Nutr. Rept. Intern. 24:443-449.

Pond, W. G., J. T. Yen and V. H. Varel. 1988. Response of growing swine to dietary copper and clinoptilolite supplementation. Nutr. Rept. Intern. 37:795-803.

Saskatchewan Pork International. 2000. Mitchell's Gourmet Foods Inc. Hog Settlement Grid.

Shurson, G. C., P. K. Ku, E. R. Miller and M. T. Yokoyama. 1984. Effects of zeolite or clinoptilolite in diets of growing swine. J. Anim. Sci. 59:1536-1545.

Statistical Analysis System Institute, Inc. 1990. SAS Users Guide, Version S. SAS Institute Inc., Cary, NC.

Taverner, M. R., R. G. Campbell and R. S. Biden. 1984. A note on sodium bentonite as an additive to grower pigs diets. Anim. Prod. 38:137-139.

Varell, V. H., I. S. Robinson and W. G. Pond. 1987. Effect of dietary copper sulphate, Aureo SP250, or clinoptilolite on ureolytic bacteria found in the pig large intestine. Appl. Environ. Microbiol. 53:2009-2013.

Ward, T. L., K. L. Watkins, L. L. Southern, P. G. Hoyt and D. D. French. 1991. Interactive effects of sodium zeolite-A and copper in growing swine: Growth, and bone and tissue mineral concentrations. J. Anim. Sci. 69:726-733.