Title: Manipulation of Swine Diets to Reduce Odors and Harmful Gaseous Emissions from Manure – **NPB #97-1791**

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1. Abstract

Four experiments were conducted to assess the effects of feeding low protein diets with supplemental amino acids (lysine, threonine, and tryptophan) and the addition of various dietary additives on the emission of volatile gasses from swine manure in simulated anaerobic manure pits. Gasses monitored were ammonia (NH_4), hydrogen sulfide (H_2S), methane (CH_4) and carbon dioxide (CO_2). Reducing the dietary protein level from 16 to 10% resulted in a linear reduction (P<.01) in NH_3 emissions from the manure. Also, manure pH was linearly (P<.01) reduced as dietary protein was reduced. There was a strong relationship between NH_3 emission and pH of the manure, with the lower pH resulting in less NH_3 emissions. The H_2S level tended to be lower with reduced dietary protein level, but CH_4 and CO_2 emissions did not follow any consistent pattern. The addition of zeolite (clinoptilolite), yucca extract, a modified carbohydrate (inulin), or a microbial product to an 18% protein diet reduced NH_3 emissions by 9, 15, 29, and 38%, respectively, and reduced H_2S emissions by 7, 11, 6, and 11%, respectively. The reduction in NH_3 from the microbial product was significant (P<.10). In comparison, a 4 percentage point reduction in dietary protein reduced NH_3 and H_2S emissions by 29 and 2%, respectively. Volatile fatty acid concentrations in the manure were not consistently affected by the additives. The results indicate that NH_4 and possibly H_2S emissions from swine manure can be reduced by lowering the dietary protein and supplementing with amino acids or by the addition of certain additives to the diet.

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2. Introduction

Two major environmental issues that the swine industry is facing as it moves into the next century are problems associated with excess nutrient excretion and odors from swine manure. Both have received considerable attention recently in the popular press and at numerous conferences in the USA and abroad.

Nitrogen (N) and phosphorus (P) are the two major elements upon which most of the attention has focused. While N in swine manure has value as fertilizer, often more N is applied than is needed by plants, and the excess N potentially becomes an environmental contaminant. Excess nitrate N leaches into groundwater and N compounds are released into the air. Phosphorus may be an even greater potential problem because it is often added to land in greater abundance relative to plant needs than is N. Excess P accumulates in soil and moves into surface waters via erosion where it stimulates algae and other aquatic plant growth and ultimately leads to deterioration of water quality.

Odors from intensive swine production facilities may be an even greater problem than manure, and these problems likely will intensify in the future as urbanization encroaches on agricultural land. Odors and other gaseous emissions from swine manure are not only a nuisance factor, but they also contribute to a deterioration in air quality. Aerial ammonia (NH_3), hydrogen sulfide (H_2S), methane (CH_4), and other volatile gasses cause reduced animal performance due to increased incidence of respiratory problems. At high levels, CH_4 and H_2S are dangerous both to pigs and people working in swine buildings.

Several countries, particularly those in the European Union, have enacted or are considering regulations which will govern the permissible levels of N and P production and/or N emissions from swine facilities. The swine industry in the USA may soon face much greater government regulation which in turn may make sustainability more difficult, unless these effects are better understood and mitigated.

Diet manipulation has clearly been shown to reduce excess N and P in swine manure. Additionally, diet manipulation offers the potential to assist in reducing the real or perceived negative effects of odors and other gaseous emissions from swine waste. However, very little research has been done to specifically quantify the amount of reduction in gaseous emissions that can be achieved by diet manipulation. To date, the only gas that has been studied to any degree is NH_3. Additional research is needed to assess the effects of diet manipulation and of specific feed additives on gaseous emissions of NH_3, H_2S, CH_4, and other volatile gasses in swine manure.

3. Objectives

The overall goal of this proposed study was to assess the potential impact of diet manipulation on NH_3 and other gaseous emissions that cause odors from a simulated anaerobic swine manure pig. The specific objectives were as follows:

1. To determine the effects of reducing the dietary protein level and supplementing with amino acids on the emission of volatile gasses (NH_3, H_2S, CH_4, and CO_2) from swine manure in a simulated anaerobic manure pit.

2. To evaluate the effects of dietary additions of a yucca extract, a microbial product, zeolite, and inulin on emission of these gasses.

4. Procedures

General. This study represents a collaborative effort by investigators in the Animal Sciences Department and the Biosystems and Agricultural Engineering Department at the University of Kentucky. Four experiments were conducted. Experiments 1 and 2 addressed the first objective, and Experiments 3 and 4 addressed the second objective. Crossbred finishing barrows having medium-high lean growth rate were used in the studies. The pigs were fed corn-soybean meal diets fortified with minerals and vitamins to meet their requirements, and various dietary treatments were imposed.

Manure (urine and feces) was collected from the pigs and placed in simulated anaerobic pits (30 gallon, covered, individually ventilated containers) to determine gaseous emissions of NH_3, H_2S, CO_2, and CH_4. Sample identity was maintained so that each container represented an individual pig (in Experiments 1 and 2) or an individual pen (in Experiments 3 and 4). There were 12 separate containers allowing for three replications of each of the dietary treatments. The waste containers were placed in a controlled environment where negative pressure was applied using an exhaust tube and fan system designed to approximate the air flow rates commonly used in commercial farm manure pit ventilation systems on a volumetric rate per unit area basis.

Air samples were collected from each container at 10-minute intervals and NH_3, CO_2, and CH_4 were measured with a multi-gas monitoring system configured from two manufacturers of high-quality gas sampling equipment. One unit utilized a photo acoustic infra-red detection system. Also, H_2S was measured by electrochemical sensors that rely on a diffusive process. The complete system included a microprocessor-based controller to sequence valves and automatic sampling. Measurements were taken during the loading period and for several weeks thereafter, depending on the experiment.

In the latter three experiments, pH of the manure was determined periodically with a pH probe, and samples of manure were taken at the end of the test for volatile fatty acid (VFA) determinations using gas-liquid chromatography methods.

Experiment 1. Twelve pigs averaging 183 lb were placed in stainless steel metabolism crates designed for complete collection of feces and urine. The pigs were equally fed, within replication, four diets for a 14-day period. There were three replications per treatment. Diets were as follows:

1. High protein (16%)
2. Adequate protein (14%)
3. Reduced protein (12%) + lysine
4. Low protein (10%) + lysine, threonine, and tryptophan

The amino acids were added to meet the calculated requirements for those amino acids that were deficient in the 12 and 10% protein diets. Manure was collected from each pen and loaded daily into 12 containers (simulated manure pits), and four volatile gasses (NH_3, H_2S, CO_2, CH_4) were monitored continuously during the loading period and a subsequent 14-day period.

Experiment 2. Twelve pigs averaging 115 lb were placed in stainless steel metabolism crates. The pigs were equally fed, within replication, four diets for a 14-day period. There were three replications per treatment. Diets were as follows:

1. High protein (16.6%)
2. Adequate protein (14.6%)
3. Reduced protein (12.6%) + lysine
4. Low protein (10.6%) + lysine, threonine, and tryptophan

The amino acids were added to meet the calculated requirements for those amino acids that were deficient in the 12 and 10% protein diets. Manure was collected from each pen and loaded daily into 12 containers (simulated manure pits), and NH_3, H_2S, CO_2, and CH_4 were monitored continuously during the loading period and a subsequent 14-day period. Samples of the waste were collected at periodic intervals for determination of pH and VFA concentrations.

Experiment 3. Due to the inability of the gas detection system to detect any H_2S, a change was made in the manure collection protocol in order to collect a greater quantity of manure. The rationale was that larger quantities of manure that could be stored deeper in the simulation pits (containers) would increase the chances of anaerobic decomposition resulting in H_2S emissions. An initial test with conventional manure indicated that the greater quantity of manure did result in detection of H_2S emissions.

Eighty-four pigs averaging 51 lb were placed in 4 ft x 8 ft pens with plastic coated, expanded metal floors in a temperature-controlled building. Manure was collected in plastic pans under the floors. Four diets containing 18% protein were fed on an ad libitum basis for 6 days. There were three pen-replications of seven pigs each per treatment. Diets were as follows:

1. Basal (18% protein)
2. Basal + *Yucca schidigera* extract (Ultimate Gold®, 4 lb/ton)
3. Basal + microbial product (MicroSource "S"®, 1 lb/ton)
4. Basal + fructooligosacchride (inulin, 60 lb/ton)

Manure was quantitatively collected on days 5 and 6 and loaded into simulated manure pits. Gasses (NH_3, H_2S, CO_2, and CH_4) were monitored continuously for 40 days, including the loading period. The pH of the manure was measured three times, and manure samples were collected twice for VFA concentrations.

Experiment 4. Thirty-six pigs averaging 71 lb were placed in 4 ft x 8 ft pens with plastic coated, expanded metal floors in a temperature-controlled building. Manure was collected in plastic pans under the floors. Two 18% protein diets and one 14% protein diet were fed on an ad libitum basis for 15 days. There were three pen-replications of four pigs each per treatment. Diets were as follows:

1. Basal (18% protein)
2. Basal + zeolite (clinoptilolite, 40 lb/ton)
3. Low protein (14%) + lysine, threonine, and tryptophan

Manure was quantitatively collected on days 12 and 13 and loaded into simulated manure pits; then it was collected again on days 14 and 15 and loaded into simulated pits. Gasses (NH_3, H_2S, CO_2, and CH_4) were monitored continuously for 23 days, including the loading period. The pH of the manure was measured weekly, and manure samples were collected at the end of the study for VFA concentrations.

5. Results

Experiment 1. The results are shown in Table 1. The NH_3 concentrations in the simulated manure pits were highest in pigs fed the highest dietary protein level and lowest in pigs fed the lowest dietary protein level. The CO_2 and CH_4 concentrations were not affected by dietary protein level in any consistent pattern. The system was not able to detect H_2S emissions in any of the treatment groups.

Experiment 2. The results are shown in Table 2. The NH_3 concentrations in the simulated pits were dramatically influenced by the level of dietary protein fed to the pigs. The NH_3 concentrations decreased linearly ($P<.01$) from 21.4 to 10.1 ppm as dietary protein decreased from 16.6 to 10.6% in the diet. Levels of CH_4 tended to be higher as dietary protein level was reduced, but the differences were not significant ($P=.20$). Concentrations of CO_2 were not affected by treatment, and levels of H_2S were nondetectable.

Manure pH on days 7, 14, 19, and 28 decreased linearly ($P<.01$) as dietary protein was reduced. The lower the dietary pH, the less NH_3 was emitted by the manure. VFA concentrations were not consistently affected by dietary protein level except for butyric acid and valeric acid, which tended to increase (linear, $P<.15$) as dietary protein level decreased.

Experiment 3. The results are shown in Table 3. Each of the additives (yucca, microbials, inulin), when added to the diet, tended to decrease the manure NH_3 levels, but only the decrease resulting from the microbial additive treatment approached significance ($P<.10$). Nevertheless, the yucca, microbial product, and inulin additions reduce NH_3 rather substantially, by 15, 38, and 29%, respectively. Although detectable, the levels of H_2S measured were all substantially less than 0.1 ppm, or 1% of full scale (10 ppm) of the instrument. Nevertheless, each additive reduced the H_2S levels numerically, but the reductions were small (11, 11, and 7%, respective). Each of the additives tended to reduce manure pH, but the differences were not significant. VFA concentrations were numerically affected by dietary treatment, but valeric acid concentration was the only one that was significantly ($P<.10$) affected by any of the additives; it was increased by the inulin addition.

Experiment 4. The results are shown in Table 4. Blower and duct failures which occurred during portions of this experiment account for gaps in the data collected and may have contributed to greater variation in measured gas concentration levels during this experiment as opposed to the first three experiments. Zeolite addition tended to reduce NH_3 and H_2S concentrations (by 9 and 7%, respectively), but the differences were not significant. Zeolite addition did result in a slight, 2.3% decrease in CO_2 emission that was significant ($P<.03$). As observed in Experiments 1 and 2, reducing the dietary protein level and supplementing with amino acids was associated with less NH_3 emission from the manure (30% reduction in NH_3 concentration), and a lower pH in the manure (12% reduction in pH units).

Overall Effects of Dietary Protein and Additives. Figures 1 and 2 show that reducing the dietary protein level clearly reduces the NH_3 emissions from swine manure in simulated anaerobic manure pits, and this reduction in NH_3 emissions is associated with a reduction in manure pH. Figures 3 and 4 illustrate the overall effectiveness of the four feed additives that were tested on NH_3 and H_2S emissions from pig manure. Note that each of the additives numerically reduced NH_3 and H_2S concentrations. Zeolite, yucca extract, inulin, and the microbial product reduced NH_3 emissions by 9, 15, 29, and 38%, respectively, and reduced H_2S emissions by 7, 11, 6, and 11%, respectively. However, only the reduction in NH_3 from the microbial product was statistically significant ($P<.10$). In comparison, a 4 percentage point reduction in dietary protein reduced NH_3 and H_2S emissions in manure by 29 and 2%, respectively. Only very small readings for H_2S concentrations were detected during any of the experiments, rendering conclusions made from the H_2S concentration data somewhat suspect.

These results indicate that NH_4 and possibly H_2S emissions from swine manure can be reduced by lowering the dietary protein and supplementing with amino acids or by the addition of certain additives to the diet.

Table 1. Summary of Results - Experiment 1 (UK Experiment 9714)

	High Protein	**Adequate Protein**	**Reduced Protein+L**[a]	**Low Protein+AA**[a]
Crude protein, %:	**16**	**14**	**12**	**10**
Lysine, %:	**.78**	**.65**	**.65**	**.65**
No. pigs	3	3	3	3
Avg weight, lb	184.1	176.4	185.2	184.8
Daily feed intake, lb	5.63	5.63	5.71	5.71
Mean concentration of gasses, ppm				
NH_3	16.8	14.1	16.1	13.3
CO_2	491	521	493	490
CH_4	27.2	29.1	27.0	27.3
H_2S	nd[b]	nd	nd	nd

[a]L=lysine (.15%). AA=amino acids: lysine (.30%), threonine (.08%), and tryptophan (.03%).
[b]None detected.

Table 2. Summary of Results - Experiment 2 (UK Experiment 9721)

	High Protein	Adequate Protein	Reduced Protein+L[a]	Low Protein+AA[a]	SE
Crude protein, %:	**16.6**	**14.6**	**12.6**	**10.6**	
Lysine, %:	**.85**	**.70**	**.70**	**.70**	
No. pigs	3	3	3	3	
Avg weight, lb	114.0	115.3	114.3	115.0	
Daily feed intake, lb	4.43	4.53	4.55	4.32	
Mean concentration of gasses, ppm					
NH_3[c]	21.40	13.81	13.47	10.13	2.17
CO_2	552	544	554	551	5.89
CH_4	1.56	1.59	2.15	2.25	.43
H_2S	nd[b]	nd	nd	nd	
Manure pH					
Day 7[c]	8.33	7.97	7.51	6.81	.29
Day 14[c]	8.06	7.70	7.21	6.82	.22
Day 19[c]	7.88	7.64	7.31	6.68	.22
Day 28[c]	7.90	7.69	7.35	6.68	.23
Average[c]	8.04	7.75	7.35	6.75	.22
Manure volatile fatty acids, mM					
Day 28					
Acetic acid	145.9	108.9	117.1	134.3	22.65
Propionic acid	29.4	23.7	29.8	44.1	6.91
Isobutyric acid	8.7	6.6	9.1	10.8	1.40
Butyric acid[d]	22.5	20.9	38.8	49.8	7.62
Isovaleric acid	8.2	6.1	8.6	9.2	1.33
Valeric acid[e]	3.4	2.6	5.7	8.0	1.46

[a]L=lysine (.15%). AA=amino acids: lysine (.30%), threonine (.09%), and tryptophan (.04%).
[b]Non detected.
[c]Linear effect of dietary protein (P<.01).
[d]Linear effect of dietary protein (P<.10).
[e]Linear effect of dietary protein (P<.15).

Table 3. Summary of Results - Experiment 3 (UK Experiment 9804)

Item	Basal	Yucca	Microbials	Inulin	SE
No. pigs	21	21	21	21	
Avg weight, lb	51.2	51.1	51.2	51.1	
Daily feed intake, lb	3.55	3.51	3.51	3.35	
Mean concentration of gasses, ppm					
NH_3[a]	9.30	7.87	5.79	6.59	1.33
CO_2	461	462	448	462	7.37
CH_4	6.70	7.24	6.53	7.35	.94
H_2S	.0281	.0249	.0250	.0263	.006
Manure pH					
Day 21	7.22	7.04	6.99	6.75	.27
Day 32	7.28	7.28	7.37	7.05	.21
Day 40	7.33	7.10	7.33	7.07	.14
Average	7.27	7.14	7.23	6.95	.20
Manure volatile fatty acids, mM					
Day 21					
Acetic acid	72.4	80.5	81.6	78.5	15.30
Propionic acid	22.9	27.9	32.8	39.1	9.59
Isobutyric acid	5.9	5.9	5.2	5.4	7.11
Butyric acid	27.3	29.3	25.0	34.9	5.88
Isovaleric acid	4.1	4.1	3.6	3.4	.36
Valeric acid[b]	5.1	4.8	4.6	9.0	1.42
Day 40					
Acetic acid	51.3	62.6	55.9	57.3	11.08
Propionic acid	17.5	23.4	20.3	25.2	7.18
Isobutyric acid	7.3	7.5	8.4	8.0	1.75
Butyric acid	24.4	28.2	32.5	37.9	11.65
Isovaleric acid	7.1	7.0	7.1	6.3	1.36
Valeric acid[b]	4.6	4.4	6.4	9.9	2.16
Average					
Acetic acid	61.9	71.6	68.8	67.9	12.45
Propionic acid	20.2	25.7	26.6	32.1	8.11
Isobutyric acid	6.6	6.7	6.8	6.7	1.21
Butyric acid	28.9	28.8	28.7	36.4	8.58

Isovaleric acid	5.6	5.5	5.3	4.9	.83
Valeric acid[b]	4.9	4.6	5.4	9.4	1.74

[a]Basal vs microbials (*P*<.10).
[b]Basal vs inulin (*P*<.10).

Table 4. Summary of Results - Experiment 4 (UK Experiment 9810)

	Basal	Zeolite	Low Protein + AA[a]	
Crude protein, %:	**18**	**18**	**14**	
Lysine, %:	**.95**	**.95**	**.95**	**SE**
No. pigs	12	12	12	
Avg weight, lb	71.9	72.1	72.1	
Avg daily feed, lb	3.64	3.72	3.69	
Mean concentration of gasses, ppm				
NH_3	8.19	7.49	5.80	1.51
CO_2[b]	434	424	432	2.43
CH_4	3.96	4.15	3.42	.80
H_2S	.0140	.0130	.0137	.0015
Manure pH				
Initial	6.80	7.03	6.31	.20
Day 7[c]	6.85	7.10	6.08	.31
Day 14[d]	6.91	7.09	6.15	.26
Day 21[d]	7.00	7.25	6.18	.28
Day 27[e]	7.15	7.14	6.17	.28
Average (excluding initial)[d]	6.98	7.15	6.14	.28
Manure volatile fatty acids, mM				
Day 27				
Acetic acid	91.5	103.1	59.8	27.7
Propionic acid	47.1	47.8	45.4	20.7
Isobutyric acid	5.7	6.0	4.2	1.74
Butyric acid	41.3	49.6	44.7	23.1
Isovaleric acid	4.0	4.6	3.0	.92
Valeric acid	8.0	4.8	13.1	3.43

[a]AA= amino acids; added lysine (.30%), threonine (.09%), and tryptophan (.04%).
[b]Basal vs zeolite ($P<.03$).
[c]Basal vs low protein diet ($P<.15$).
[d]Basal vs low protein diet ($P<.10$).
[e]Basal vs low protein diet ($P<.05$).

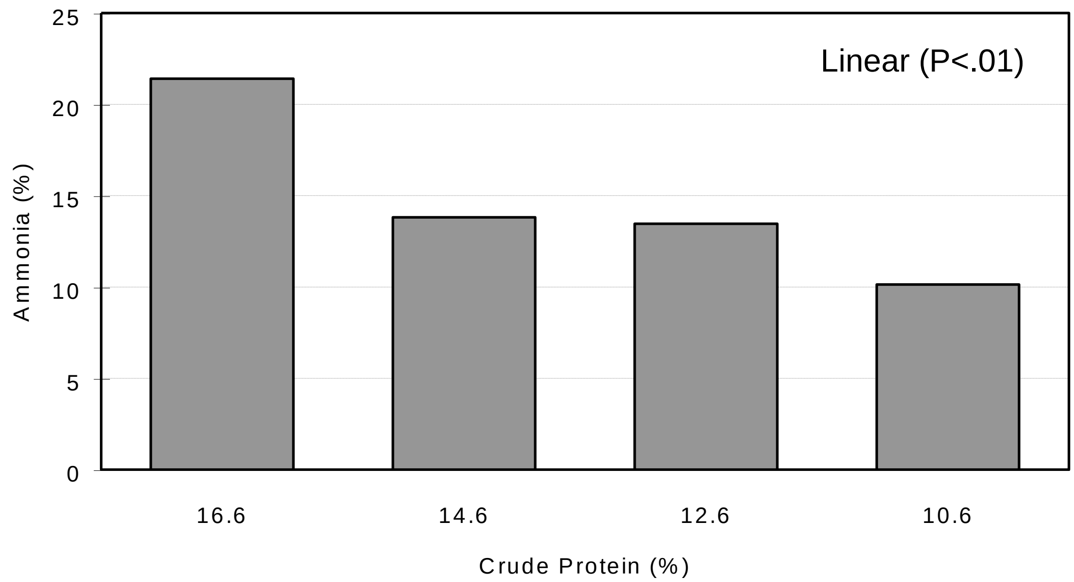

Figure 1. Effects of feeding diets with various protein levels to finishing pigs on ammonia emission from their manure as measured by ammonia concentrations above simulated anaerobic manure pits.

Figure 2. Effects of feeding diets with various protein levels to finishing pigs on pH of their manure stored in simulated anaerobic manure pits.

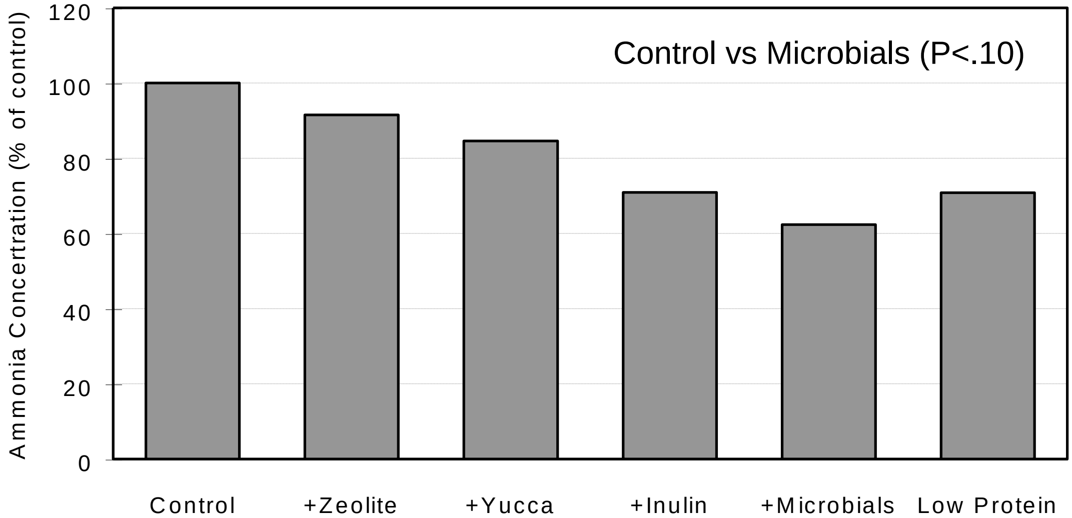

Figure 3. Effects of feeding an 18% protein diet (control) with dietary additions of a zeolite (clinoptilolite), an extract from *Yucca schidigera*, a fructooligosaccharide (inulin), or a microbial product (MicroSource "S"), or feeding a 14% protein diet with supplemental amino acids to young pigs on ammonia emission from their manure, as measured by ammonia concentrations above simulated anaerobic manure pits.

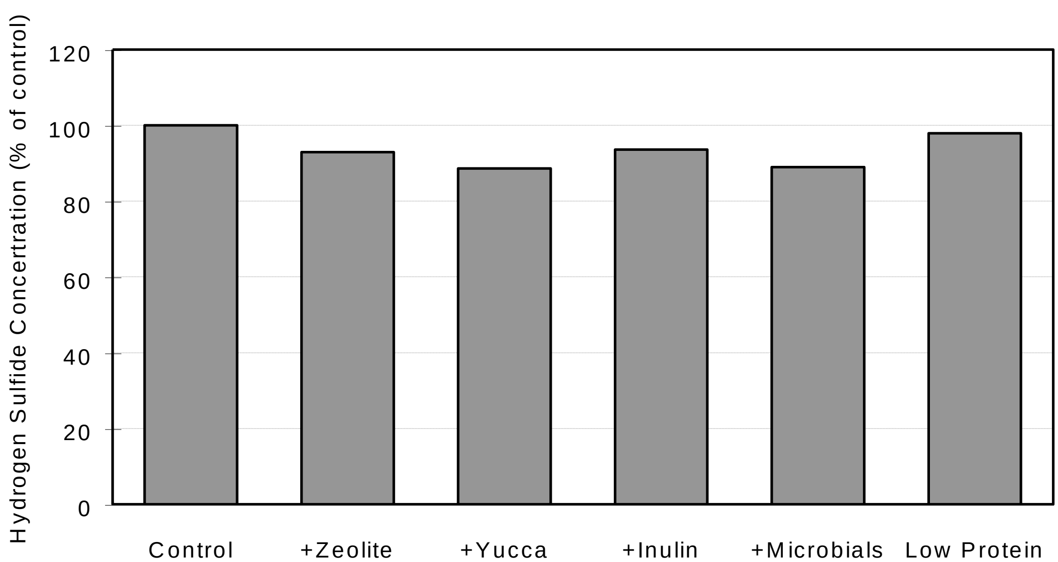

Figure 4. Effects of feeding an 18% protein diet (control) with dietary additions of a zeolite (clinoptilolite), an extract from *Yucca schidigera*, a fructooligosaccharide (inulin), or a microbial product (MicroSource "S"), or feeding a 14% protein diet with supplemental amino acids to young pigs on hydrogen sulfide emission from their manure, as measured by hydrogen sulfide concentrations above simulated anaerobic manure pits.