RESEARCH REPORT
ENVIRONMENT

Title: Direct Measurement of Dietary and Management Strategy Impacts on Ammonia Volatilization – NPB #02-013

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Abstract: Two feeding trials were conducted to quantify the effects of dietary strategies on NH_3 emissions of growing-finishing pigs. In Exp 1, nine growing pigs were fed corn-soybean meal diets fortified with no amino acids (17.4% CP), Lys (17.0% CP), or Lys, Met, Thr, and Trp (14.5% CP). In Exp 2, nine growing pigs were fed the Lys diet with 0, 62.5 or 125 ppm of yucca extract (Alltech®). Two gilts and one barrow were allocated to each of three indirect calorimeters. Four 1-wk feeding periods, with new diets assigned weekly, consisted of a 4-d dietary adjustment followed by 72 h of continuous NH_3 measurement from chamber exhaust. Pigs and feed refusals were weighed, urine and fecal samples collected, and manure pits cleaned after each period. Feed intake (FI) and gain (ADG) were measured each period. Diets, urine, and fecal samples were analyzed for TKN and NH_3-N concentration. In Exp 1 and 2, diet had no effect on FI, ADG, or feed efficiency ($P > 0.05$). In Exp 1, TKN in feces (3.97, 3.93, 3.72%; $P < 0.001$) and urine (1.10, 0.94, 0.93%, $P = 0.04$) decreased with decreasing dietary CP. Fecal NH_3-N decreased with decreasing dietary CP (0.47, 0.47, 0.42%, $P = 0.01$) while urine NH_3-N increased (0.10, 0.10, 0.20%, $P < 0.001$). Weekly NH_3-N emissions were 22.25, 19.22, and 11.85 g (± 8.87 SEM; $P > 0.05$). The fraction of excreted TKN emitted as NH_3 during the week was 1.68, 1.52, and 0.91% (± 0.60 SEM; $P > 0.05$). In Exp 2, there was a significant linear response to increasing yucca content for urine NH_3-N (0.14, 0.13, 0.11%, $P = 0.05$). Fecal TKN (3.59% ± 0.06 SEM), fecal NH_3-N (0.48% ± 0.03 SEM), urine TKN (0.94% ± 0.07 SEM), NH_3-N emissions (12.02 g ± 2.81 SEM) and the fraction of excreted TKN emitted as NH_3 during the week (1.20% ± 0.24 SEM) were not affected by diet ($P > 0.05$). Reducing diet CP and including NH_3-binding agents can be effective in reducing N content of excretions and NH_3 emissions. Less than 2% of excreted N was volatilized as NH_3 during the collection period.

Introduction: Regulation of ammonia emissions is on the near horizon for animal operations. Research has proven that nitrogen (N) excretion and ammonia emission potential can be reduced through diet manipulation. In the cited ammonia emission studies, *in vitro* and mass balance methods as opposed to direct measurement of ammonia volatilization were employed. The amount of ammonia volatilized was *assumed* to be the difference between nitrogen intake and measured nitrogen excretion. This raises the question of whether the N is lost as ammonia or in some other form. Limited work to measure ammonia loss directly has looked at emissions from farm-scale housing environments. That work has examined the influence of ventilation type and rate as well as accumulated manure storage and weather conditions. However, the impact of diet has not been considered using direct measurement, particularly for swine production. Research is being conducted at other universities to develop systems such as scrapers or belts to segregate feces from urine, but their quantitative effects on ammonia emissions remain to be investigated.

Objectives:

- Conduct exploratory studies to evaluate dietary effects on ammonia emissions from grower-finisher swine
- Evaluate fecal–urine segregation, pH adjustment, and urease inhibition impact on ammonia release

Materials & Methods:

Dietary effects on ammonia emissions

Animal housing and emissions measurement

Pigs of approximately 100 lb, starting weight, were pen-housed in four environment-controlled chambers ($5 \times 6 \times 8$ ft each). Urine and feces were allowed to fall through the slatted floor and was contained in the shallow pits within each chamber environment. Each chamber was equipped with a precision air mass flow meter. Airflow rate multiplied by ammonia concentration of the uniformly mixed exhaust air, provided ammonia emission measures. Ammonia concentration of was measured in each chamber using a 30-min sampling cycle and continuous consecutive cycling through exhaust air of each of the three chambers followed by the incoming air. The environmental conditions and parameters related to the measurement of ammonia emission rates and were automatically collected via a PC-based environment control and data acquisition system.

Diets

In Exp 1, nine pigs (initial BW = 103 lb) were fed corn-soybean meal diets fortified with no amino acids (17.4% CP, CONTROL), Lys (17.0% CP, LYS), or Lys, Met, Thr, and Trp (14.5% CP, LYS+MTT). In Exp 2, nine pigs (initial BW = 90 lb) were fed the Lys diet with 0, 62.5 or 125 ppm of yucca extract (Alltech®, LYS, LYS+62.5, LYS+125). Two gilts and one barrow were allocated to each of three indirect calorimeters. Diet formulation is provided in Table 1. Allocation of diets to each chamber for each of the feeding experiments is depicted in Table 2.

Table 1.

	Reduced crude protein trial			Yucca trial		
	Control	LYS	LYS+MTT	LYS	LYS+62.5	LYS+125
Formulation						
Corn	78.77	82.00	87.30	82.00	82.00	82.00
Soybean meal	19.20	15.80	10.14	15.80	15.79	15.79
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin/mineral premix	0.20	0.20	0.20	0.20	0.20	0.20
Calcium carbonate	0.58	0.62	0.65	0.62	0.62	0.62
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00
Lysine		0.13	0.32	0.13	0.13	0.13
Methionine			0.03			
Threonine			0.08			
Tryptophan			0.03			
Yucca extract					.00625	.0125
Analyzed composition						
Crude protein, %	17.2	15.9	14.4	15.7	15.7	15.7
TDN, %	84	85	84	84	84	84

Table 2. Treatment allocation to three indirect calorimeters during four feeding periods within each experiment.

	Reduced crude protein trial			Yucca trial		
	Chamber 1	Chamber 2	Chamber 3	Chamber 1	Chamber 2	Chamber 3
Week 1	Control	LYS	LYS+MTT	125 ppm	62.5 ppm	0 ppm
Week 2	LYS	CONTROL	LYS+MTT	125 ppm	0 ppm	62.5 ppm
Week 3	LYS +MTT	CONTROL	LYS	0 ppm	125 ppm	62.5 ppm
Week 4	LYS	LYS+MTT	CONTROL	62.5 ppm	0 ppm	125 ppm

Experimental design

For each feeding experiment four 1-wk feeding periods, with new diets assigned weekly, consisted of a 4-d dietary adjustment followed by 72 h of continuous NH_3 measurement from chamber exhaust. Pigs and feed refusals were weighed, urine and fecal samples collected, and manure pits cleaned after each weekly period. Feed intake (FI) and gain (ADG) were measured each weekly period. Diets, urine, and fecal samples were analyzed for TKN and NH_3-N concentration. Mass balance of N intake and N excretion calculated in order to determine what fraction on N loss is actually lost as NH_3. Data were analyzed using a general linear model of SAS. Main effects were treatment and chamber within diet. Week was treated as a repeated measure. For the yucca extract trial, treatment served as a continuous independent variable in order to evaluate a dose-response relationship.

Management strategy effects on ammonia emissions

Strategies

Six specific post-excretion strategies were investigated. These were 1) acidification/neutralization where sulfuric acid or sodium hydroxide or nothing was added to manure to produce final pH's of 5.3, 6.6, and 8.8; 2) temperature alteration where manure was stored at room temperature (25° C) or heated to 35° or 42° C; 3) manure was stirred continuously or not stirred at all; 4) addition of DeOdorase to manure at two concentrations (0.0074 g/ L and 0.0149 g/ L) or no addition; 5) addition of Agrotain to manure at two concentrations (0.076 ml/ L and 0.152 ml/ L) or no addition; and 6).

Experimental design

Following collection, treatment schemes were applied using lab-scale manure storage vessels, allowing for greater replication. Urine and feces were collected from finishing pigs fed a typical industry diet (no amino acid supplementation) and mixed in proportion to that excreted, based on ASAE Standard D384.1 Manure Production and Characteristics. Manure was diluted two-fold with deionized water before adding 1 L to a 2-L manure storage vessel. Each treatment was filled in triplicate with triplicate vessels for each storage time (24, 48, 72, 96 h). Prior to addition to vessels, manure was sampled (0 h) and analyzed for nitrogen, ammonia-nitrogen, and dry matter content. At the end of each storage time, vessel contents were sub-sampled and analyzed for nitrogen, ammonia-nitrogen, and dry matter content. Headspace ammonia content of each vessel was measured at the end of the storage time using Draeger tubes. Nitrogen content (mass) of the headspace was calculated from nitrogen concentration (Draeger tubes) and headspace volume. Each test period tested a single management strategy due to limitation of number of vessels.

Data were analyzed using a general linear model of SAS whereby treatment was the main effect and time was a continuous independent variable. In a separate model, time served as a discrete variable to allow for determination of least squares means at each of the time points.

Results:

Dietary effects on ammonia emissions

Discussion of treatment effects on NH3 emissions (cumulative and by day), total N losses, excreta composition

Reduced crude protein experiment. Diet had no effect on feed intake, ADG, or feed efficiency (F:G, $P > 0.05$; Table 3). The TKN in feces (3.97, 3.93, 3.72%; $P < 0.001$; Table 4) and urine (1.10, 0.94, 0.93%, $P = 0.04$; Table 4) decreased with decreasing dietary CP. Fecal NH_3-N decreased with decreasing dietary CP (0.47, 0.47, 0.42%, $P = 0.01$; Table 4) while urine NH_3-N increased (0.10, 0.10, 0.20%, $P < 0.001$; Table 4).

Weekly NH_3-N emissions were 22.25, 19.22, and 11.85 g (± 8.87 SEM; $P > 0.05$; Table 5). The fraction of excreted TKN emitted as NH_3 during the week was 1.68, 1.52, and 0.91% (± 0.60 SEM; $P > 0.05$; Table 5).

Yucca extract experiment. Diet had no effect on feed intake, ADG, or feed efficiency (F:G, $P > 0.05$; Table 3). There was a significant linear response to increasing yucca content for urine NH_3-N (0.14, 0.13, 0.11%, $P = 0.05$; Table 4). Fecal TKN (3.59% ± 0.06 SEM; Table 4), fecal NH_3-N (0.48% ± 0.03 SEM; Table 4), and urine TKN (0.94% ± 0.07 SEM; Table 4) were not affected by diet ($P>0.05$).

NH_3-N emissions (12.02 g ± 2.81 SEM; Table 5) and the fraction of excreted TKN emitted as NH_3 during the week (1.20% ± 0.24 SEM; Table 5) were not affected by diet ($P>0.05$).

Table 3. Least squares means of animal performance of pigs fed diets containing varying crude protein content (Experiment 1) and a commercial product that acts as an ammonia-binding agent (Experiment 2). Data is expressed per pen (n = 3) of pigs.

Measure[1]	Diet			SEM[2]	P-value
Experiment 1	*CONTROL*	*LYS*	*LYS+MTT*		
Feed intake, kg/pen wk^{-1}	46.9	48.0	49.6	5.6	0.9454
ADG, kg/pen	2.4	2.6	1.9	0.3	0.1990
F:G ratio	2.8	2.7	3.7	0.3	0.0890
Experiment 2	LYS	LYS+62.5	LYS+125	SEM	P-value
Feed intake, kg/pen wk^{-1}	41.6	41.4	44.7	3.3	0.7434
ADG, kg/pen	2.4	2.2	2.7	0.4	0.7793
F:G ratio	2.6	3.6	2.6	1.1	0.7679

[1]ADG = average daily gain, F:G = feed to gain conversion ration
[2]SEM = standard error of the mean

Table 4. Least squares means of excretion composition from pigs fed diets containing varying crude protein content (Experiment 1) and a commercial product that acts as an ammonia-binding agent (Experiment 2). Data is expressed per pen (n = 3) of pigs.

Measure[1]	Diet			SEM[2]	P-value
Experiment 1	*CONTROL*	*LYS*	*LYS+MTT*		
Fecal TKN, %	3.97	3.93	3.72	0.04	0.0007
Fecal NH_3-N, %	0.47	0.47	0.42	0.01	0.0112
Urine TKN, %	1.10	0.94	0.93	0.05	0.0440
Urine NH_3-N, %	0.10	0.10	0.20	0.006	<0.0001
Experiment 2	LYS	LYS+62.5	LYS+125	SEM	P-value
Fecal TKN, %	3.58	3.60	3.58	0.06	0.9573
Fecal NH_3-N, %	0.45	0.49	0.50	0.03	0.4420
Urine TKN, %	1.05	0.61	0.86	0.07	0.1790
Urine NH_3-N, %	0.14	0.13	0.11	0.01	0.0511

[1]TKN = Total Kjeldahl nitrogen (sum of organic + ammonia (NH_3) nitrogen)
[2]SEM = standard error of the mean

Table 5. Least squares means of calculated nitrogen excretion, measured ammonia emissions, and fraction of nitrogen excreted that was emitted as ammonia from pigs fed diets containing varying crude protein content (Experiment 1) and a commercial product that acts as an ammonia-binding agent (Experiment 2). Data is expressed per pen (n = 3) of pigs.

Measure	Diet			SEM[1]	P-value
Experiment 1	*CONTROL*	*LYS*	*LYS+MTT*		
N excreted, g/pen	1044.8	957.3	935.3	86.8	0.6632
NH_3 emissions, g/ pen wk-1	22.3	19.2	11.8	8.9	0.7122
Fraction of excreted N emitted as NH_3, %	1.68	1.52	0.91	0.60	0.6598
					Linear
Experiment 2	LYS	LYS+62.5	LYS+125	SEM	P-value
N excreted, g/pen	866.3	803.3	806.9	83.9	0.8435
NH_3 emissions, g/ pen wk-1	11.83	12.62	11.62	2.81	0.9660
Fraction of excreted N emitted as NH_3, %	1.14	1.26	1.20	0.24	0.9374

[1] SEM = standard error of the mean

Management strategy effects on ammonia emissions

The initial source of manure (0 hour) was the same within each treatment scheme. However, manure was collected for each treatment scheme separately, therefore not allowing comparisons between treatment schemes.

Nitrogen content of manure following storage was only affected by the temperature and the segregation treatments (Table 6). Temperature means for manures stored at 24°, 35°, or 42° C were 0.36, 0.34, and 0.35%, respectively across all storage times. No explanation is available at this time. Total nitrogen content of the feces, urine, and mixed manure was 0.54, 0.79, and 0.63% as would be expected given normal routes of nitrogen excretion in the pig and the effect of mixing urine and feces together. Storage time influenced total nitrogen content for the pH and both additive treatments (Table 6) although no directional trend was observed as storage time progressed for any of the three treatments.

Table 6. Means of nitrogen content of manure samples (%, wet basis) following post-excretion amendment and 24, 48, 72, or 96 hours of storage.

Treatment	24 h	48 h	72 h	96 h	P-value		
					Treatment	Hour	Trt x h
Stirring					0.4809	0.1686	<0.0001
Stirred	0.35	0.41	0.38	0.39			
Unstirred	0.39	0.37	0.39	0.37			
Temperature					0.0045	0.1274	<0.0001
24° C	0.36	0.36	0.37	0.35			
35° C	0.32	0.30	0.35	0.38			
42° C	0.37	0.37	0.33	0.36			
Segregation					<0.0001	0.2744	0.0025
Urine	0.79	0.80	0.80	0.78			
Feces	0.54	0.51	0.52	0.58			
Mixed	0.61	0.63	0.63	0.63			
pH					0.9720	<0.0001	0.0818
Acidic	0.31	0.31	0.32	0.32			
Basic	0.31	0.32	0.32	0.31			
Unaltered	0.30	0.32	0.33	0.32			
Agrotain					0.2054	0.0011	0.5154
0 ml/L	0.46	0.36	0.32	0.42			
0.076 ml/L	0.34	0.32	0.31	0.42			
0.152 ml/L	0.37	0.32	0.31	0.46			
DeOdorase					0.6407	0.0182	0.0008
0 mg/L	0.39	0.40	0.40	0.40			
7.4 mg/L	0.40	0.40	0.40	0.40			
14.9 mg/L	0.40	0.40	0.40	0.39			

Ammonium nitrogen content of the vessels demonstrated treatment and storage time effects for all treatments except the two additive treatments (Table 7). Only storage time effects were observed for the two additive treatments. In all six treatments schemes (stirring, temperature, segregation, pH, DeOdorase, and Agrotain) the ammonium nitrogen content increased with storage time reflecting a conversion of organic nitrogen to inorganic nitrogen due to nitrogen breakdown under the storage conditions provided. Mechanical mixing of manure increased ammonium nitrogen content (0.153% vs. 0.146%) as did increasing storage temperature (0.138%, 0.152%, and 0.193% for 24°, 35°, or 42° C).Ammonium nitrogen content was lowest in the urine (0.082%) followed by feces (0.092%) whereas combination of urine and feces, as a result of urease activity, was considerably greater (0.400%). As pH was increased from acidic conditions (pH =

5.3) to neutral (pH = 6.6 representing unaltered manure) to basic conditions (pH = 8.8), ammonium nitrogen content increased from 0.116% to 0.127% to 0.141%.

Table 7. Means of ammonium nitrogen content of manure samples (%, wet basis) following post-excretion amendment and 24, 48, 72, or 96 hours of storage.

Treatment	24 h	48 h	72 h	96 h	P-value		
					Treatment	Hour	Trt x h
Stirring					<0.0001	<0.0001	0.0200
Stirred	0.14	0.15	0.16	0.17			
Unstirred	0.13	0.14	0.15	0.16			
Temperature					<0.0001	<0.0001	0.0005
24° C	0.13	0.13	0.14	0.14			
35° C	0.13	0.14	0.16	0.18			
42° C	0.16	0.20	0.19	0.22			
Segregation					<0.0001	<0.0001	<0.0001
Urine	0.07	0.08	0.08	0.09			
Feces	0.09	0.09	0.09	0.10			
Mixed	0.33	0.40	0.43	0.44			
pH					<0.0001	<0.0001	<0.0001
Acidic	0.12	0.11	0.12	0.12			
Basic	0.13	0.14	0.15	0.15			
Unaltered	0.12	0.13	0.13	0.14			
Agrotain					0.0905	<0.0001	0.5504
0 ml/L	0.14	0.13	0.15	0.17			
0.076 ml/L	0.11	0.12	0.12	0.17			
0.152 ml/L	0.12	0.13	0.15	0.17			
DeOdorase					0.9419	<0.0001	<0.0001
0 mg/L	0.13	0.12	0.14	0.15			
7.4 mg/L	0.12	0.13	0.14	0.15			
14.9 mg/L	0.11	0.14	0.14	0.15			

Treatment effects on headspace ammonia content were observed for all schemes. Mechanical mixing of manure increased headspace ammonia content (10.3 vs. 4.7 ppm, Table 8) as did increasing temperature (4.3 , 5.2, and 40.7 ppm for 24°, 35°, and 42° C, respectively). Headspace ammonia content was similar for both urine and feces, alone (1.2 and 1.8 ppm) but combining the two had a dramatic effect on concentration (237.5 ppm NH_3). Headspace ammonia was below the limit of detection of the method for vessels containing the acidified manure. However, increasing pH from 6.6 to 8.8 increased ammonia concentration in the headspace more than 9-fold (1.5 vs. 12.9 ppm). The limit of detection of the Draeger tubes used to measure concentration is 1 ppm. Therefore, reducing pH to 5.3 reduced ammonia headspace concentration by at least one-third. Addition of Agrotain actually increased ammonia headspace concentration (1.7, 2.8 and 4.0 ppm for the 0, 0.076, and 0.152 ml/L additions) despite the products marketing as an ammonia inhibitor. Addition of DOdorase, on the other hand, did decrease ammonia headspace concentration (2.1, 1.8, 1.5 ppm for 0, 7.4, and 14.9 mg/L addition), demonstrating an almost 30% reduction when the product was added at twice the manufacturer's recommended feeding concentration, and a 15% reduction when added at the recommended feeding concentration.

Table 8. Means of headspace ammonia content of manure storage vessels (ppm) following post-excretion amendment and 24, 48, 72, or 96 hours of storage.

Treatment	24 h	48 h	72 h	96 h	P-value		
					Treatment	Hour	Trt x h
Stirring					<0.0001	<0.0001	0.0010
Stirred	9.50	4.75	10.02	16.75			
Unstirred	0.58	6.67	2.25	9.40			
Temperature					<0.0001	<0.0001	<0.0001
24° C	3.30	4.20	4.70	5.00			
35° C	3.00	3.00	5.10	9.75			
42° C	12.60	47.00	54.60	48.50			
Segregation					<0.0001	0.5931	0.5781
Urine	0.30	1.80	0.84	1.73			
Feces	0.10	0.63	2.08	4.20			
Mixed	255.00	220.00	245.00	230.00			
pH					<0.0001	<0.0001	0.0013
Acidic	------	0.45	0.68	0.33			
Basic	4.75	17.50	14.50	14.75			
Unaltered	0.78	1.73	1.60	1.73			
Agrotain					<0.0001	<0.0001	0.0001
0 ml/L	0.400	1.59	1.60	3.00			
0.076 ml/L	2.10	1.70	2.55	4.65			
0.152 ml/L	1.25	1.73	4.15	8.78			
DeOdorase					0.0105	<0.0001	0.3267
0 mg/L	0.36	3.45	1.93	2.68			
7.4 mg/L	0.38	2.75	2.05	1.95			
14.9 mg/L	0.38	2.60	1.35	1.65			

Discussion: Immediately following excretion, urease, secreted in the feces, has the opportunity to breakdown urea in the urine. At that point, ammonia is formed and can remain in the urine or volatilize. Strategies to decrease N excretion also result in reduced potential for N volatilization. Therefore, feeding pigs reduced crude protein diets that are supplemented with synthetic amino acids to meet the amino acid needs is a logical strategy to pursue. Indeed, substantial research exists to verify this theory. What has been lacking, however, is quantification of ammonia emission reductions that occur when lysine, methionine, threonine, and even tryptophan are incorporated. This project tested the effects of dietary strategies previously shown to be effective at reducing N inputs without production losses on ammonia emissions.

As a result of the proposed effort we have direct measurements of dietary potential to alleviate ammonia volatilization from animal manure. Our results indicate that while the diets selected did not adversely impact animal performance, as measured by feed conversion efficiency and animal weight gain, inclusion of lysine, methionine, threonine, and tryptophan into swine diets reduced ammonia emissions (measured directly) by 50% compared to the control diet (no amino acid supplementation). Dietary crude protein content was reduced by 16% in the diet with four amino acids compared to the control diet. Nitrogen excretion, calculated from measured urine and fecal nitrogen content and estimated volume of urine and fecal excretion, was reduced by 10% compared to the control diet.

Feeding of the ammonia binding agent significantly affected urine ammonia nitrogen content, only. A linear reduction was observed as quantity of product fed increased linearly. However, given that the potential for ammonia emission stems from nitrogen excretion in the urine, the observed reduction in urinary ammonia nitrogen content suggests that the agent is worthy of closer investigation.

Our data showed that less than 2% of the calculated nitrogen excreted was emitted as ammonia from the animal facilities during the weeklong feeding period. While

generally thought is that all of the excreted nitrogen has the potential to volatilize as ammonia, our data demonstrate the importance of using direct measures to quantify ammonia emissions.

Using ammonium nitrogen content and headspace ammonia concentration as indicators of ammonia emission potential, segregation of urine and feces, clearly demonstrated the greatest potential to reduce emissions. However, it must be acknowledged that only the manure used in the segregation trial was not first frozen prior to the testing. Freezing may have slowed bacterial activity to where conversion to ammonium nitrogen was considerably less in the remaining five trials, underestimating the potential of these five strategies. Further investigation of this is warranted before any sound comparisons of treatment schemes can be made.

Lay Interpretation: As stated in the contract, we require a lay interpretation of the project, suitable for public release by the Board. Please include contact information, should the public want to contact you directly.

A study conducted at Iowa State University, by university scientists and researchers from the USAD-ARS Swine Odor and Manure Management Unit evaluated the independent effects of diet and post-excretion manure treatment on ammonia emission from swine manure.

Findings of the diet study conclude that incorporation of crystalline amino acids into swine diets can reduce ammonia emissions by 15% (lysine inclusion, only) to almost 50% (inclusion of lysine, methionine, threonine and tryptophan). This resulted from a reduction in dietary crude protein content of 10% (lysine inclusion, only) to 16% (inclusion of lysine, methionine, threonine and tryptophan).

Post-excretion strategies tested included mechanical mixing of manure, temperature effects (24° (room temperature), 35°, and 42° C), segregation of urine and feces, pH adjustment, and the use of two commercial products marketed to reduce ammonia emissions. Stirring increased manure ammonium nitrogen content and headspace ammonia content in the storage containers. Similarly, increasing temperature above room temperature resulted in substantial increases in both components (10-40% for manure ammonium nitrogen content and 21-946% increase in headspace ammonia concentration) suggesting that the effect of chilling manure is worthy of investigation. Segregating urine and feces maintained manure ammonium nitrogen content below 0.1%. However, when mixed, the concentration increased 4-fold to 0.4%. Similarly, combining urine and feces resulted in increased headspace ammonia content from less than 2 ppm (urine or feces, alone) to 237 ppm (urine + feces). Reducing manure pH by just over 1 pH unit reduced headspace ammonia content by greater than one-third while increasing pH from 6.6 to 8.8 pH units increased ammonia by 860%. Addition of DeOdorase to manure resulted in a linear reduction in headspace ammonia content (15 to 30%) as the amount added was increased from one to two times the recommended addition.

The results suggest that the combination of diet and post-excretion effects should be studied in combination. Future work should also be conducted to allow comparisons between post-excretion strategies, something which can only be inferred from the current study. Regardless, the current study demonstrates that options are available to effectively curtain ammonia emissions, at least in the short-term. Economic evaluation of the tested strategies has not yet been conducted.

Through information such as this, proposed ammonia emission reduction strategies can be developed to minimize the impact of potential future regulations on swine producers and provide the producers with tools with which to comply if new regulation does come about.