

# Effects of Dietary Manipulation on Ammonia Emissions

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**Species:** Swine  
**Use Area:** Animal Housing  
**Technology Category:** Diet Modification  
**Air Mitigated Pollutants:** Ammonia

## Description:

Ammonia emission from swine housing is primarily dependent on the amount of nitrogen excreted by swine. Nitrogen excretion is influenced by dietary protein level, digestibility of the dietary protein, amino acid balance, and genetics of the pig. A portion of the dietary protein consumed by the pig is excreted in the feces and urine. Fecal nitrogen is predominantly composed of undigested dietary protein. Urinary nitrogen is excreted primarily in the form of urea. Urea, when combined with feces in the pit, is enzymatically digested to ammonia. Ammonia emission from swine housing is an environmental concern and improvements in the utilization of dietary protein can provide benefits of decreasing ammonia emissions.

The most widely used method to decrease nitrogen excretion and, therefore, ammonia emission from swine housing is the use of lower protein diets with amino acid supplementation. Lowering crude protein content of the diet with amino acid supplementation for growing-finishing pigs has been shown to decrease nitrogen excretion and ammonia concentration of the manure (Sutton et al., 1999). Kerr et al. (1995) reported an 8 to 10% decrease in nitrogen excretion by swine for every 1 percentage unit reduction in dietary crude protein. Additionally, marked decreases in ammonia concentration or emission in anaerobically-stored manure in simulated pits have been reported (Sutton et al. 1999).

Another potential mechanism to further reduce ammonia concentration or emission from swine housing is the use of fermentable carbohydrates (fiber) in the diet. Fiber addition to diets has been shown to alter the proportion of nitrogen excreted in the feces and urine (Cahn et al, 1998; Shriver et al., 2003). By increasing the proportion of nitrogen excreted in the feces and reducing the proportion of nitrogen excreted in the urine as urea, ammonia emissions can be reduced (Sutton et al., 1999). While numerous studies have reported decreases in nitrogen excretion and(or) reductions in ammonia emission due to dietary manipulation, a majority of these studies were performed using individual pigs and simulated manure pits.

Lachmann et al. (2007) reported a 31% decrease in total nitrogen excretion, a 37% reduction in ammonium nitrogen concentration of the slurry, and a 56% reduction in ammonia emissions for pigs fed a diet with crude protein concentration reduced by three percentage units with amino acid supplementation during a 110-day finishing period. Bundy et al. (2008) reported similar effects for pigs fed a diet with crude protein reduced by three percentage units. Additionally, in this study, the addition of a fiber source (soybean hulls) further reduced ammonium nitrogen concentration in the slurry, and a further numerical decrease in ammonia emissions was noted during a 112-day finishing period.

Additional benefits of lowering dietary crude protein and adding fiber to diets reported by Lachmann et al. (2007) and Bundy et. al. (2008) included:

- Decreased pH of the slurry
- Decreased concentration of ammonia in the swine house, better environment for workers
- No effect on growth performance and carcass traits

## Mitigation Mechanism:

Ammonia volatilization from the waste treatment system in swine houses is dependent on temperature, air velocity, moisture content, waste storage system (deep pit vs. shallow pit), pH, and ammonium concentration. Lowering crude protein content of the diet with amino acid supplementation reduces nitrogen excretion. The decrease in nitrogen excretion reduces the concentration of ammonium in the slurry which, in turn, decreases ammonia emission.

Additionally, the reduction in ammonium concentration of the slurry also reduces slurry pH which affects ammonia volatilization. Addition of fiber sources to the diet reduces urinary urea excretion which can be degraded enzymatically to ammonia. The reduction in crude protein content or addition of fiber sources to swine diets can reduce or change nitrogen excretion patterns resulting in marked decreases in ammonia emissions for pigs housed in facilities with shallow pit, pull-plug waste storage systems. Furthermore, the decrease in ammonia improves indoor air quality for not only the workers, but also for the pigs.

## Applicability:

The use of dietary manipulation is an effective method to reduce ammonia emissions from swine in the finishing phase. Lowering crude protein content of the diet by 3 percentage units with appropriate amino acid supplementation can reduce ammonia emission by over 50% compared with pigs fed typical corn-soybean meal diets from 28 to 118 kg (65 to 260 lb). Moreover, addition of a fiber source, such as soybean hulls, to a low protein diet can further reduce ammonia emissions.

## Limitations:

The use of low protein diets with amino acid supplementation is dependent on knowledge of the amino acid requirements of the pig. Failing to meet the lysine requirement or inadequate supplementation of other amino acids in relation to lysine when using low protein diets may decrease growth performance and carcass merit of finishing pigs. Lowering crude protein by up to 3 percentage units with adequate amino acid supplementation does not affect growth performance or carcass traits. However, further reductions in crude protein (>3%) have been reported to decrease carcass merit in some studies.

The use of fiber in diets is dependent on accurate nutrient analysis of the source in order for optimum diet formulation. Also, the use of fiber (soybean hulls) in diets is limited to approximately 10 to 15% of the diet. Dietary levels greater than 10 to 15% could potentially reduce growth performance. It is also important to note that addition of fiber can potentially increase dry matter excretion which translates to an increase in total solids content of the slurry.

Additionally, the cost of crystalline amino acids must be weighed when deciding whether to incorporate low protein diets in the feeding program of finishing pigs. It is recommended that producers utilize a nutritionist to formulate low protein diets or diets containing fiber in order to reduce the risk of effects on growth performance and(or) carcass traits and to minimize diet costs.

## Cost:

In the studies discussed here, there were no effects of dietary treatment on pig performance and carcass traits. Thus, implementation decisions are based on ingredient costs. Formulation of low protein diets involves the partial removal of soybean meal from the diet accompanied by replacement with corn and crystalline amino acids (lysine HCl, DL-methionine, L-threonine). Therefore, evaluation of implementation cost weighs the decrease in soybean meal costs versus the increase in corn and amino acid costs within the diet. Using March 2008 ingredient costs of \$0.044/kg (\$5.40/bu) for corn and \$0.077/kg (\$340/ton) for dehulled soybean meal, the diet costs for the two treatments used in this study were \$0.298/kg (\$0.135/lb) for the control diet and \$0.295/kg (\$0.134/lb) for the low protein, amino acid supplemented diet. Cost of gain equaled \$0.841 and 0.823/kg (\$0.381/lb, \$0.373/lb) and total feed cost for the finishing period (28 to 118 kg) equaled \$70.9 and \$68.6/finished pig, respectively, for the control and low protein, amino acid supplemented diet.

## Implementation:

The results reported in this document are based on two experiments using finishing pigs (Bundy et al., 2008; Lachmann et al., 2007). In both experiments, crossbred pigs initially weighing 28 kg (65 lb) were housed in a finisher building containing four identical rooms, each with a shallow pit, pull plug waste storage system. Pigs and feeders were weighed weekly during a 16-week finishing period in order to determine growth performance. Slurry in the pits was collected each week during the 16-week period and used to calculate nutrient excretion. Additionally, ventilation rate and ammonia concentration of the exhaust air was monitored continuously for each room during the finishing period. Ventilation rate and ammonia concentrations were used to calculate emission rates for ammonia.

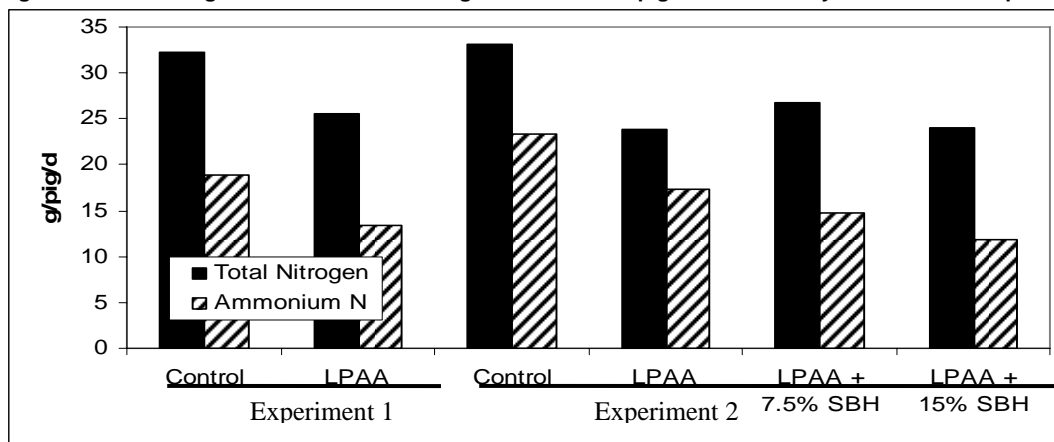
In each experiment, pigs were fed in four dietary phases during the finishing phase. In both experiments, a similar control and low protein, amino acid supplemented diet was fed (Table 1). The control diet was a typical, fortified corn-soybean meal based diet formulated to meet the lysine requirement of the pig. In the low protein, amino acid supplemented diet, crude protein concentration was reduced by 3 percentage units and lysine was added to maintain lysine levels similar to the control diet. Additional amino acids (threonine, methionine) were added to this diet on an ideal basis. Additionally, phosphorus concentration was reduced by 0.10% and phytase was added. In Experiment 2, two additional dietary treatments were employed. Soybean hulls were added to the low protein diet at 7.5 and 15% in order to examine the effects of fiber addition to the diet.

**Table 1. Dietary composition of the control and low protein, amino acid supplemented (LPAA) diets for the four dietary phases used in Exp. 1 and 2 (as-fed basis)**

Ingredient, %	Phase 1		Phase 2		Phase 3		Phase 4	
	Control	LPAA	Control	LPAA	Control	LPAA	Control	LPAA
Corn	65.72	74.24	71.30	79.90	76.71	85.37	80.54	89.16
SBM, 48% CP	29.11	20.58	23.66	15.07	18.30	9.73	14.58	6.12
L-lysine		0.27		0.28		0.27		0.27
DL-methionine		0.01						
L-threonine		0.08		0.09		0.07		0.04
L-tryptophan		0.01		0.01		0.01		
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium P	0.61	0.26	0.54	0.20	0.47	0.12	0.39	0.04
Limestone	0.97	0.98	0.94	0.90	0.93	0.88	0.90	0.85
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin mix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
TM mix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Antibiotic	0.10	0.1	0.10	0.10	0.10	0.10	0.10	0.10
Phytase		0.02		0.02		0.02		0.02
Diet cost, \$/lb	0.141	0.139	0.136	0.136	0.132	0.133	0.130	0.126
Calculated composition, %								
ME, kcal/kg	3483	3487	3490	3494	3494	3501	3499	3508
CP, %	19.3	16.3	17.2	14.2	15.1	12.1	13.6	10.6
Lysine, %	1.05	1.03	0.90	0.88	0.75	0.73	0.65	0.63
Ca, %	0.60	0.50	0.56	.044	0.52	0.40	0.48	0.36
P, %	0.50	0.40	0.46	0.36	0.43	0.33	0.40	0.30

In Experiment 1, feeding the low protein, amino acid supplemented diet reduced nitrogen excretion by 31%, ammonium nitrogen concentration of the slurry by 37%, and reduced ammonia emissions by 56% (Figure 1). In Experiment 2, similar results decreases in nitrogen excretion and ammonium nitrogen concentration of the slurry were observed for pigs fed the low protein, amino acid supplemented diet (Figure 1). Addition of soybean hulls to the low protein, amino acid supplemented diet in Experiment 2 did not affect total nitrogen excretion, but further reduced ammonium nitrogen concentration of the slurry.

**Figure 1. Total nitrogen and ammonium nitrogen excretion for pigs fed the dietary treatments in Experiment 1 and 2.**



Ammonia emissions for pigs in each experiment and housed in this shallow pit, finisher building is shown in Table 2. Air ventilation rate was similar between rooms within each experiment. Ammonia concentration (mg/m<sup>3</sup>), emission rate (mg/min), and total emission on a per pig basis were reduced in each experiment by feeding the low protein, amino acid supplemented diet. These reductions in ammonia emission were obtained without any effect on growth performance, carcass traits, or feed costs.

**Table 2. NH<sub>3</sub> emissions for pigs fed the dietary treatments in each experiment during a 116-d finishing period.**

	Experiment 1 <sup>a</sup>		Experiment 2 <sup>b</sup>			
	Control	LPAA	Control	LPAA	LPAA + 7.5% SBH	LPAA + 7.5% SBH
NH <sub>3</sub> , mg/m <sup>3</sup>	0.863	0.418	2.52	1.76	1.27	1.29
NH <sub>3</sub> , mg/min	29.78	12.80	71.3	36.4	32.5	30.2
NH <sub>3</sub> , g/pig/d	2.32	1.02	1.95	0.99	0.88	0.82
NH <sub>3</sub> , g/d-AU	15.5	6.4	11.85	6.04	5.15	4.66

<sup>a</sup>Experiment 1 utilized 20 pigs per room and was conducted from July through November.

<sup>b</sup>Experiment 2 utilized 22 pigs per room and was conducted from January through April.

Additionally, in these studies, growth performance, carcass traits, or measures of carcass composition were not affected by dietary treatment. Thus, producers that implement the use of low protein, amino acid supplemented diets to decrease nitrogen excretion and mitigate ammonia emissions should not experience effects on growth performance, carcass traits, or feed costs of finishing pigs. However, these results are dependent on correct diet formulation and not exceeding a 3 percentage unit reduction in crude protein.

## Technology Summary:

The use of low protein, amino acid supplemented diets is an effective method to decrease nitrogen excretion and mitigate ammonia emissions from swine finisher facilities. Reduction of protein in the diet reduces total nitrogen excretion by the pig. The decrease in total nitrogen excretion (specifically urea nitrogen) reduces the substrate available for ammonia volatilization. Additionally, slurry pH is reduced which also decrease ammonia emissions. Addition of fiber to low protein, amino acid supplemented diets has the potential to further decrease urinary urea nitrogen excretion and, thus, ammonia emissions. These results can be obtained without adverse effects on growth performance and carcass traits of finishing pigs. However, these results are dependent upon adequate amino acid supplementation to the diet. With correct dietary formulation, increases in diet cost can be avoided and, thus, feed cost/pig is similar to a conventional corn-soybean meal diet. Producers are urged to work with a swine nutritionist before implementing these types of diet to decrease the risk of potential negative effects on growth performance, carcass traits, or diet cost. Also, further reductions in dietary crude protein beyond 3 percentage units should be discussed with a nutritionist. Dietary manipulation is an effective method to mitigate ammonia emissions and should be considered as a first line of defense in a whole farm approach to mitigating ammonia emissions.

## Additional Resources:

Diet effects on manure nutrients <http://www.pork.org/porkscience/Environment/ManureMgmt.aspx?c=DietEffects#one>

Managing nutrient excretion and odor in pork production through nutrition <http://www.porkgateway.org/>

Understanding and applying nutrition concepts to reduce nutrient excretion in swine  
<http://mark.asci.ncsu.edu/Nutrition/Environ/concepts.pdf>

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