Management Impacts on Ammonia Volatilization from Swine Manure

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Summary and Implications

Ammonia released from swine manure into the air is becoming an increasingly controversial topic in Iowa. This experiment was conducted to evaluate the potential of several management strategies to reduce ammonia volatilization from swine manure over time. In six benchtop trials using twenty-four 1-L manure storage vessels, treatments were applied to the vessels, and manure and air samples were analyzed for concentrations of ammonia and other forms of nitrogen. Segregated storage of urine and feces, keeping manure cool and still, addition of yucca extract, and acidification reduced ammonia volatilization.

Introduction

Ammonia is an air pollutant that contributes to environmental and human health problems. Swine manure is the source of an estimated 10% of all ammonia emitted in the U.S. About 63% of the nitrogen in swine manure is believed to volatilize as ammonia and other gases under normal production conditions. A laboratory experiment was conducted to study the effects of six types of management strategies on the volatilization of ammonia and nitrogen content of swine manure during short-term storage.

Materials and Methods

Fresh manure was collected from pens housing grow-finish pigs and diluted 1:1 with water. The total Kjeldahl nitrogen (TKN) and ammonium-N content of the slurry was analyzed prior to storage in sealed vessels made of PVC pipe. The 24 vessels were each filled with 1 L of manure, and had 1 L of headspace, where ammonia and other gases accumulated. Treatments applied to the vessels included modification of storage temperature, continuous agitation, addition of a urease inhibitor (N-(n-butyl) thiophosphoric triamide, NPBT; Agrotain International LLC, St. Louis, MO) and a nitrogen-binding product (De-Odorase™;Alltech Inc., Nicholasville, KY), segregation of urine from feces, and pH manipulation. Duplicate vessels were used for each combination of treatment and storage time, and each strategy was evaluated in a separate trial. After 24, 48, 72, or 96 hours of storage, the ammonia concentration of the headspace air was measured using Dräger tubes (Dräger Safety Inc., Pittsburgh, PA) with a bellows pump, and the slurry was again analyzed for TKN and ammonium-N content. Storage time effects are not included in this report and will be reported elsewhere.

The mass of ammonia-N volatilized from each vessel was calculated from the headspace ammonia concentrations using the Ideal Gas Law. Nitrogen loss was calculated as the difference in TKN contained in the manure of each vessel before and after storage. Changes in slurry nitrogen composition and volatility during storage were evaluated by comparing the percent of TKN in the form of ammonium-N. Data were analyzed using the SAS statistics program and a general linear model. The model evaluated effects of treatments and storage time. Significance was declared at $P \leq 0.05$.

Results and Discussion

Data from each trial are depicted in Table 1. Segregation of urine from feces showed great potential for preventing both ammonium-N formation and ammonia release (Table 1). By storing urine and feces in separate vessels, ammonia released into the headspace was reduced to less than 1% of the amount measured when the excreta were mixed. Segregated management of excreta may largely prevent urinary urea from being broken down by urease that is in feces.

Acidification to a pH of 5.3 decreased ammonium-N concentration 9% and the percent of TKN in the form of ammonium by 8%, while increasing the slurry pH to 8.85 resulted in increased headspace ammonia concentration. The reaction that converts ammonium (NH_4^+) in manure slurries to ammonia gas (NH_3) is pH-dependent, and acidic conditions prevent the reaction from progressing.

The yucca extract, De-Odorase, reduced ammonia volatilization in a dose-dependent manner without significantly affecting slurry ammonium-N concentration or the percent of TKN in the form of ammonium. While yucca did not change the amount of ammonium-N present in the slurry, it prevented the ammonium from being released into the headspace air as ammonia.

The urease inhibitor, NBPT, was not effective at reducing headspace ammonia concentrations in this experiment. Slurry ammonium-N formation was not changed, so urease inhibition was not observed. This may have been due to release of urea, with subsequent ammonia volatilization, prior to manure collection. Ammonia volatilization increased with increasing addition of NBPT to the slurry. It is unclear why the NBPT had this unexpected effect on ammonia release.

Warmer temperatures and continuous agitation increased both slurry ammonium-N concentrations and ammonia volatilization. Keeping manure below 42°C and undisturbed during storage may prevent ammonia volatilization by discouraging the biochemical reactions that produce ammonium and by keeping the manure-headspace boundary undisturbed.

In those treatments where ammonium-N concentrations were different from the control, the percent difference was similar to the change in fraction of TKN as ammonium. While the total nitrogen content of the manure was unchanged, the volatility of that nitrogen was impacted. Over time, volatile ammonium-N will be lost to the air, potentially representing both an environmental threat and a loss of manure fertilizer value.

In all six trials, slurry ammonium concentrations were positively correlated (r = 0.7) with headspace ammonia concentrations. Wherever slurry ammonium concentrations became greater than in the control, ammonia releases to the headspace air were also greatly increased. Management strategies that reduce slurry ammonium formation may be just as effective in reducing ammonia losses from manure as strategies that approach volatilization more directly. To prevent ammonia volatilization at the point of excretion, segregated management of urine and feces is a promising strategy. Keeping manure slurries cool, unstirred, and at a low pH could help prevent or slow ammonium formation. The addition of a nitrogen-binding product could then reduce the amount of ammonium-N volatilized as ammonia.

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Table 1. Percent difference in post-storage (24, 48, 72, and 96 h) slurry nitrogen composition and headspace ammonia-N concentrations compared to experimental controls.

Treatment	Slurry ammonium-N, g per 100 g	Treatment P =	Percent of TKN[1] as ammonium-N	Treatment P =	Headspace ammonia-N, mg per m^3	Treatment P =
Mixed urine + feces		< 0.0001		< 0.0001		< 0.0001
Urine alone	- 80%		- 84%		- 99%	
Feces alone	- 77%		- 73%		- 99%	
Unaltered pH (6.59)		< 0.0001		< 0.0001		<0.0001
Acidified (pH 5.3)	- 9%		- 8%		- 75%	
Alkalized (pH 8.85)	+ 10%		+ 11%		+ 778%	
No urease inhibitor		0.58		0.78		0.01
Single dose NBPT[2]	NS[3]		NS		+ 48%	
Double dose NBPT	NS		NS		+ 130%	
No nitrogen binder		0.92		0.88		0.05
Single dose yucca	NS		NS		- 14%	
Double dose yucca	NS		NS		- 28%	
Room temperature (24°C)		< 0.0001		< 0.0001		< 0.001
35°C	+ 11%		+ 18%		+ 18%	
42°C	+ 40%		+ 40%		+ 805%	
Unstirred		< 0.01		0.02		0.02
Continuously stirred	+ 5%		+ 4%		+ 115%	

[1]Total Kjeldahl nitrogen
[2]N-(*n*-butyl) thiophosphoric triamide
[3]Differences were not statistically significant (P > 0.05).