Production and Storage Strategies for Controlling Ammonia Emissions

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Introduction

Several factors affect the release of ammonia from livestock facilities and from manure storage areas. Understanding how these factors impact volatilization forms the basis for developing practical management techniques for reducing emissions on the farm. The release of ammonia is affected by:

- Dietary crude protein
- pH of manure or litter
- Activity and availability of urease enzyme
- Presence of compounds that bind ammonia
- Moisture content of the manure
- Temperature
- Concentration gradients between manure and the air
- Air speed over the surface
- Surface area

Dietary crude protein

Dietary protein contains about 6.25% nitrogen. Almost all excreted nitrogen is in the form of urea (uric acid in poultry). When either of these compounds comes in contact with feces, an enzyme naturally present in feces, called urease, will convert the urea or uric acid to ammonia.

Formulating diets for poultry and swine on the basis of amino acids rather than crude protein can potentially reduce the total nitrogen content of the diet. This will also reduce the amount of nitrogen excreted and therefore the amount of ammonia lost through volatilization. Most producers do this already and also find it's economical to reduce supplemental protein even further by including feed grade amino acids. Here is a simple example of how a swine grow-finish diet can be reformulated with the use of lysine-HCL to reduce both nitrogen intake and excretion.

	Standard Diet, lb	Low-Protein Diet, lb
Corn	1575	1671.5
Soybean meal	375	275
Vitamins-minerals	50	50
Lysine-HCl	-	3.5
Total	2000	2000
Lysine	.80%	.80%
Crude protein	15.8	13.8
Nitrogen	2.5	2.2

By making this simple and economical dietary change, nitrogen excretion can be reduced by 12%. Further reductions of dietary protein are possible as long as additional lysine and other amino acids are added to the diet. Two other amino acids that are fairly economical are threonine and D,L methionine.

pH of the manure, litter or slurry

Ammonia present in the manure is in equilibrium with ammonium, as shown below:

$$NH_4^+ \quad + \quad \rightleftharpoons \quad NH_3 \quad + \quad H^+$$

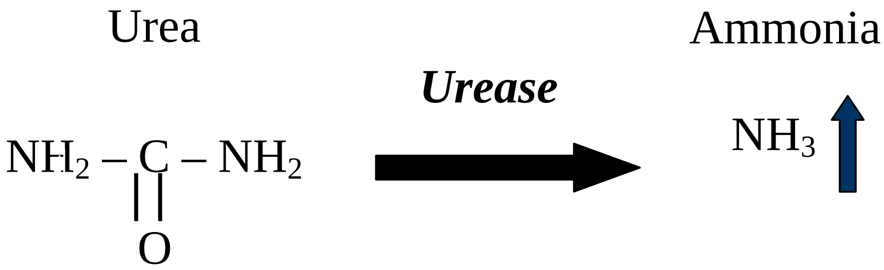
Ammonium Ammonia

When we add more H^+ ions to the system, this also lowers the pH. The more H^+ ions there are, the more likely ammonia will be converted to ammonium. As long as ammonium stays in this associated form, it will not volatilize. If the system is neutral or alkaline, then there will be fewer H^+ ions to combine with ammonia, so the free ammonia is more likely to escape to the atmosphere.

There are various methods to acidify the manure. Aluminum sulfate (alum) is frequently added to poultry litter. When it dissolves in the moisture present in the manure, hydrogen ions are released, which combine with the ammonia to form ammonium, as shown above. The ammonium goes on to combine with the sulfate, which can act as a water-soluble fertilizer. The aluminum combines with phosphorus to form a new compound with low solubility, which helps to reduce phosphorus runoff after the poultry manure has been land applied. Although alum will effectively react with other types of manure, it's used most often to treat poultry litter. Recommended rates are 50 to 200 lbs per 1000 ft of poultry floor space (Blake, 2001). Care must be taken not to add too much alum, which will increase the amount of soluble aluminum in the slurry. Other acidifying agents that have been the subject of research include calcium chloride, calcium sulfate, magnesium chloride, and magnesium sulfate (Kithome et al., 1999).

Activity of the Urease Enzyme

Urease enzyme, which catalyzes the breakdown of urea into ammonia and CO_2, is present in both soil and manure. The duration of exposure to the urease enzyme will affect the total emissions of ammonia. For example, EPA (2004) estimates that over 70% of nitrogen is lost from lagoons, which are biological active systems designed for long-term storage. The hydrolysis of urea is shown below.



There are various compounds that have been used in cropping systems to reduce urease activity. At least two of these have been shown to reduce urea hydrolysis by up to 70% in cattle manure and up to 92% in swine manure (Varel, 1997). Although ammonia emissions were not measured in this experiment, it is logical to conclude that ammonia release would have been significantly reduced. The compounds used included:

- Cyclohexylphosphoric triamide
- Phenyl phoshorodiamidate

Use of Zeolite

In addition to reducing pH and inactivating the urease enzyme, other materials can be added to the manure, which will bind with ammonia. Zeolites are clay-type minerals called aluminosilicates. They have several important properties including adsorption, cation-exchange, dehydration-rehydration and catalysis. The cation-exchange capability allows zeolite to exchange ammonium for sodium and potassium present in manures (Mumpton, 1999). The addition of 6.25% zeolite to dairy manure has been shown to reduce ammonia emissions by 50% (Lefcourt and Mesinger, 2001). When the manure is land-applied, the zeolite releases the ammonium slowly since plants are able to extract the ammonia from the zeolite (Dwairi, 1998). Furthermore, zeolite inhibits the conversion of ammonium to nitrate (called nitrification), which helps to minimize nitrate leaching (Perrin et al., 1998).

Moisture content

The release of ammonia is enhanced with moderate increases in moisture content. If the manure is very dry, ammonia emissions will be reduced. For this reason, poultry producers should always strive to minimize water wastage.

While emissions from liquid manure storages are relatively constant, ammonia release from outdoor feedlot conditions are affected by wet-dry cycles. Auvermann (2002) suggested several solutions for reducing ammonia emissions from feedlots:

- Curtailing the use of water in feedlots to control dust.
- Improving drainage in the corral by using mounds and a 3-4% slope.
- Adding a source of carbon (improves the C:N ratio and helps dry manure).
- Removing manure more often – most feed lots wait until cattle leave to clean pens.

Temperature

Ammonia emissions increase with temperature. This is due to enhanced biological and enzymatic activity, and improved diffusion of ammonia to the surface from deeper areas of the storage. These temperature-dependent factors help explain why ammonia emissions from livestock facilities and from manure storages are higher in summer months compared to that of winter (Klopfenstein, 2002). Rom (1993) reported that a change in temperature of the manure of 18 °F results in a 65% change in ammonia gas pressure from the slurry. This would suggest that storages under roof would be preferred to outdoor storage areas, which are exposed to solar radiation.

Concentration gradients and air movement

For ammonia to move out of manure into the air above, the concentration in the liquid must be higher than the concentration in air (Li, 1999). A major factor affecting the concentration of ammonia in the air layer immediately above the manure is air speed. If there is no air movement, the concentration of ammonia in the air near the manure will be relatively high – which will reduce volatilization from the manure. In outdoor conditions, wind will keep the concentration in the air at near zero, which enhances the release of ammonia from the manure storage (Li, 1999).

Surface Area

Increased surface area creates more total sites from which ammonia can escape. Stacking semi-solid manure will help reduce total surface area. Also, straw covers have been shown to reduce ammonia emissions from liquid manure storages. In fact, when a crust formed in the weeks following the straw application to dairy manure storages, ammonia emissions were reduced by 95% (Xue et al., 1999). Measurements demonstrated that the straw formed a barrier to the movement of ammonia, but there were also indications that the ammonia concentrations in liquid surface layer immediately below the straw were reduced. This suggests that biological reactions are affected by the presence of the straw material.

Another similar study confirmed that straw reduces ammonia emissions by 83-91% (Hornig et al., 1999). The same authors also applied a 1/4-inch layer of rape oil to the surface of manure under laboratory conditions and found that ammonia emissions were reduced by 85%.

Biofilters, which are sometimes used to remove odors from exhaust air, are also efficient at removing ammonia. Studies show that ammonia removal efficiencies range from 54 to 93% (Sheridan et al., 2002; Bundy, 2002).

The type of flooring also influences the amount of ammonia emissions from livestock facilities. Rom (1993) reported that partially slatted buildings emit less ammonia than either solid floored facilities (because surface evaporation is higher in solid floor systems) or totally slotted facilities (because surface area is significantly higher in totally slotted systems).

Summary

The release of ammonia is dependent upon several factors, which interact in complex ways. Perhaps the most important factors affecting ammonia emissions are control of nitrogen excretion, pH of the manure, temperature of the manure and the amount of exposed surface. Dairy, livestock and poultry producers can minimize ammonia emissions by:

- Formulating diets precisely to reduce excess protein in the feed. Non-ruminant diets should be formulated on the basis of amino acids.
- Reducing pH of the manure. The use of acidifying agents like alum can reduce ammonia emissions and also help reduce phosphorus solubility.
- Storing manure under roof will protect the storage facility from exposure to direct sunlight. This will reduce the temperature, which also reduces ammonia emissions.
- Consider covering manure with straw – this minimizes the amount of exposed surface area, which also significantly reduces ammonia emissions.

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