REDUCING IN-BARN AMMONIA EMISSIONS TO CONSERVE THE FERTILIZER NITROGEN VALUE OF DAIRY MANURE

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Introduction

Dairy farms are thought to emit large amounts of ammonia and therefore contribute to nitrogen (N) fertilization of natural ecosystems and provide precursors for particulates that adversely affect air quality and human health. The 2003 NRC report "Air Emissions from Animal Agriculture" (NRC, 2003) made an urgent call for processed-based research that assists livestock producers and regulatory agencies in developing strategies that reduce the emissions of ammonia and other gasses that impair air quality.

Only approximately 20 to 35% of the N (protein) fed to dairy cows is converted into milk (Figure 1). The remaining N is excreted in urine and feces. Feeding N to dairy cows in excess of their requirements is excreted in urine. About three-fourths of the N in urine is in the form of urea. Urease enzymes, which are present in feces and soil, rapidly convert urea to ammonium. Ammonium can be transformed quickly into ammonia gas. Feces contain little or no urea. For this reason urinary N is much more vulnerable to ammonia volatilization than is fecal N.

Dairy cows produce a lot of urine (approximately 8 gallons/day). Under current feeding and manure handling, storage, and land application techniques, most of the N contained in urine is converted to ammonia gas and lost to the atmosphere. The environmental impacts of ammonia can be broken down into two parts:

(1) How much ammonia-based compounds is actually deposited into different ecosystems, and

(2) Once deposited, how does the N cycle within each ecosystem respond to this input.

Some emitted ammonia is deposited not too far from its source (e.g., barn, lagoon, fields where manure has been applied). In Wisconsin where most dairy farms grow their own crops, approximately 20 to 30% of the emitted ammonia can be deposited on adjacent cropland. Ammonia N deposited in natural ecosystems, however, contributes to ecosystem fertilization, acidification, and the premature "ageing" of the ecosystem. This ammonia N input can cause dramatic shifts in the vegetation, enhancing grass growth and creating fire hazards in some areas. Emitted ammonia also combines with acidic compounds in the upper atmosphere to form particulates. These particulates have been related to haze in urban areas, and also have been attributed to a variety of adverse health effects, including premature mortality, chronic bronchitis, asthma, and hospital admissions.

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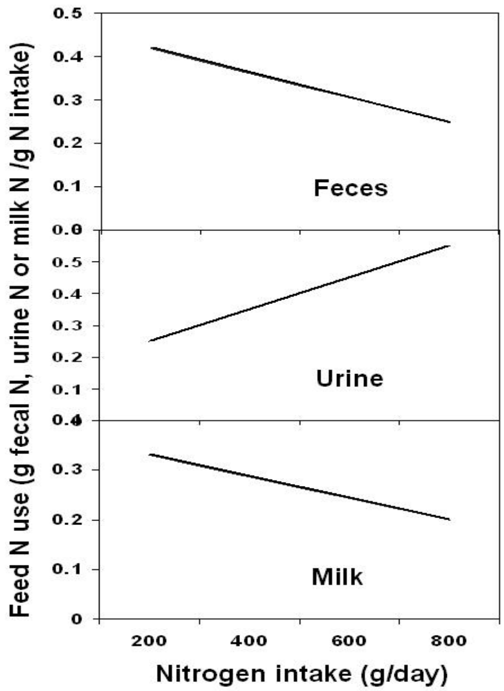
Fig. 1. Relationships between N fed to dairy cows and N secreted in milk and excreted in feces and urine (adapted from Castillo et al., 2000).



Approaches that Reduce Ammonia Losses from Dairy Barns

Ammonia production and loss occur almost immediately in the barn and continue through manure storage and land application. Because ammonia is a gas, losses are inevitable. But ammonia nitrogen loss can be reduced, and the fertilizer value of manure can be maintained through good management.

One of the most reliable approaches to reducing ammonia emissions per unit of milk produced is to increase level of milk production because, to a certain extent, emissions parallel feed intake. On Wisconsin dairy farms, the efficiency by which the crude protein contained in feed is converted into milk (i.e., feed nitrogen use efficiency) varies according to production practices. Milk production and feed N use are highest on farms that use total mixed rations (TMR), that balance rations four times per year, and milk thrice daily (Table 1). These practices put more feed nutrients into product (milk), and less into manure.

Table 1. Impact of feed management and milking frequency on milk production, and feed N use efficiencies (FNUE) on 54 Wisconsin dairy farms (Powell et al., unpubl.)

Practice	Practice use	Milk Production	FNUE
		lbs/cow/d	%
Use TMR	Yes	74a[†]	27a[†]
	No	57b	24b
Balance rations 4 times/year	Yes	67a	26a
	No	54b	21b
Milk thrice daily	Yes	88a	33a
	No	63b	25b
Use Posilac®	Yes	82a	29a
	No	61b	25b

[†]within a practice, means followed by different letters differ significantly ($P<0.05$).

Over the long term, continued genetic selection of cows for high milk production potential will be a very effective means of reducing ammonia nitrogen emissions per unit of milk produced. Furthermore, increasing production per animal would decrease the number of cows needed to meet the market demand for milk.

Protein Fed to Dairy Cows Affects Ammonia Loss

Diet formulation to eliminate excess N usually reduces feed cost, and it is one of the most effective tools for reducing emission into the atmosphere of nitrogen containing compounds from dairy farms. Nitrogen excretion by dairy cows via urine, and therefore the amount of manure N susceptible to loss, is highly influenced by the amount and type of protein fed. As the amount of protein in feed exceeds what is required, relatively less of the N goes into milk and more goes directly into urine production (Figure 1).

Significant reductions in urine production can be obtained by reducing dietary protein levels. For example, if 17.5% dietary protein currently represents an industry average for lactating cows, carefully formulated diets containing 16.0 to 16.2% crude protein, which meets requirements for the lactating cow and still provides a reasonable margin of safety, would reduce N excretion in urine by about 20% (Broderick, 2003).

Various lactation trials have been conducted whereby Holstein cows were fed different levels of crude protein (CP), fiber, corn silage, alfalfa silage, alfalfa haylage, and tannin-containing forages [alfalfa, birdsfoot trefoil low tannin (BF-T-Low) and birdsfoot trefoil high tannin (BF-T-High)]. The principal purpose of these trials was to evaluate diet impacts on milk production and composition. At the end of each trial, diet impacts on ammonia volatilization were evaluated by applying fresh or stored slurries to the surface of soils (Misselbrook et al., 2005).

Thus far, most of the tested diets have had little impact on milk production or quality, but affected the amount and relative N partitioning in urine and feces (similar pattern to what is depicted in Figure 1). Fresh and stored slurry from low CP diet had less than one-half the ammonia loss than slurries from the high CP diet (Table 2). Fresh slurry derived from BF-T-High diets had less ammonia loss than slurry from alfalfa or BF-T-Low diets. Stored slurry from BF-T-High and -Low diets had less ammonia loss than slurry derived from alfalfa.

Table 2. Cumulative ammonia emissions for fresh and stored slurries derived from different dairy diets applied to silt loam soil (Misselbrook et al., 2005).

Trial type	Trial components	Liquid manure type	
		Fresh	Stored
		% applied N volatilized	
CP level	13.6%	31b#	12b
	19.4%	68a	29a
Forage tannin type	Alfalfa	31a	30a
	BF-T-Low	33a	23b
	BF-T-High	25b	19b

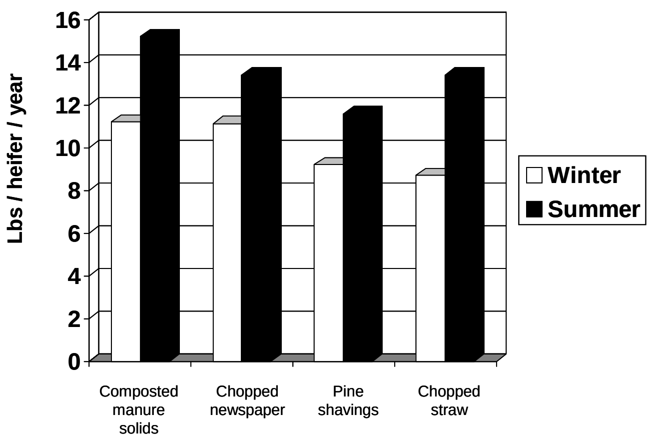
within each trial, values with different letters are significantly different (*P*<0.05)

Bedding Affects Ammonia Nitrogen Loss

Dairy cattle barns are major sources of ammonia emissions to the atmosphere. Our research is showing that the bedding material used can influence the magnitude of these emissions. The physical characteristics (urine absorbance capacity, bulk density) of bedding materials are of more importance than their chemical characteristics (pH, cation exchange capacity, carbon to nitrogen ratio) in determining ammonia emissions from applied urine and feces (Misselbrook and Powell, 2005). For example, of the bedding types commonly used in dairy barns, sand is the least and recycled manure solids the most urine absorbent. When equal volumes of urine were applied to dry bedding, ammonia emissions over 48 h were significantly lower from sand (23% of applied urine N), followed by pine shavings (42% of applied urine N), than from the other bedding types (mean 63% of applied urine N for straw, newspaper, corn stalks and recycled manure solids).

Preliminary results from in-barn trials show a similar pattern of ammonia emissions from beddings to that determined in the lab. Ammonia loss from composted manure solids was greater than from chopped straw and pine shavings (Figure 2). Because of warmer temperatures, ammonia emissions are 20 to 55% greater during the summer than during the winter. These laboratory and in-barn measurements indicate that the selection of bedding may be based not only on cow comfort and health, but also on their ability to reduce ammonia emissions.

Fig. 2. Ammonia N losses from tie-stalls using different beddings.



Impact of Ammonia Loss on Plant Availability of Manure Nitrogen

Ammonia loss from manure is important because it is a direct loss of nitrogen that is available to the farmer. Given the high potential of ammonia nitrogen loss in manure handling, storage, and land application, only a small fraction of the nitrogen excreted by a dairy cow and applied to land may actually be recycled through crops. Furthermore, the loss of ammonia also reduces the nitrogen:phosphorus ratio in manure, which may increase the risk of manure phosphorus applications in excess of crop needs. Many dairy farms have soil test phosphorus levels that exceed agronomic recommendations, and the runoff of phosphorus from these fields and subsequent pollution of lakes, streams, and other surface waters has become a principal concern.

Reducing ammonia losses from dairy farms and making greater use of conserved manure N may quickly make economic sense. Natural gas accounts for 75 to 90% of the cost of making anhydrous ammonia. As the price of natural gas continues to skyrocket, the fertilizer N value of manure, and therefore the conservation of the ammonia N contained in manure will become more important. Reducing volatile N losses would not only conserve manure N available for field applications, but also reduce the amount of carbon dioxide, a greenhouse gas, that is generated in making nitrogen fertilizer.

Conclusions

Substantial reductions in ammonia loss from dairy farms can be achieved by reducing in-barn losses, by covering manure storage, and by incorporation of manure in the field. The following steps can be a guide for action:

1. Remove excess protein from the cow's diet. This normally saves on cost of feed.
2. For new construction, floors that divert urine away from feces can reduce ammonia emissions. Slatted floors facilitate this, but there is still considerable loss of ammonia from the surface of the slatted floor.
3. Select bedding (e.g. sand, straw) that separate feces and urine, which reduce ammonia losses;
4. Cover the manure storage. When organic bedding such as straw is used in free stall, a crust will form on the surface of the slurry pit. This reduces ammonia N losses and odors. Excessive agitation during unloading of the slurry from storage should be avoided.
5. Incorporate manure in the field. However, this strategy needs to consider potential tradeoffs in situations where nitrate leaching may be a concern.

Implementation of 1, 3, 4, and 5 could potentially reduce ammonia N loss from about 115 to 30 to 40 lb/cow/yr, a 65 to 70% reduction. This means additional 70-80 lbs. N per cow would be available annually for application to field crops.

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