PENNSTATE
1855
Dairy and Animal Science
das.psu.edu

What are we losing when valuable nitrogen goes up in the air?

By A. N. Hristov, Ph.D
Associate Professor of Animal Nutrition

Excessive levels of nitrogen in animal manure represent not only a net loss to the producer, but are also a source of water and air pollution. Urine and feces of farm animals contain naturally high concentration of nitrogen, which is a key element in protein molecules. Microorganisms breakdown most of the feed proteins in the rumen of ruminant animals (cattle, sheep, goats) and a significant proportion of the nitrogen from this process ends up in urine as urea. If cattle are fed protein above their requirements for a given level of milk or meat production, the excess protein will most likely be converted to ammonia and to urinary urea and lost with manure.

In dairy cows, for example, urinary nitrogen can make up anywhere from 25 to more than 60 percent of the total nitrogen in fresh manure. Of about 9 lbs feed protein ingested per day, only about 2 to 3 lbs will be secreted as milk protein. The difference of 1 lb in milk protein (which is the difference between a low- and a high-efficient cow), would make a huge difference on nitrogen losses in manure. High nitrogen losses with manure are problematic because: (1) an expensive component of the diet (protein supplements are always the most expensive feed in an animal diet) is being wasted and (2) the farmer has to deal with high-nitrogen manure. The latter would not be such a problem, if land for manure application is not limited, the land-applied nitrogen does not exceed crop requirements, and manure nitrogen stays in manure. Unfortunately, none of these conditions is occurring in practical farming. Usually, urea in manure is rapidly hydrolyzed to two molecules of ammonium and a molecule of carbon dioxide, ammonium is converted to ammonia, and the latter is rapidly volatilized. More than 50 percent of cattle manure nitrogen can be lost through volatilization as ammonia in 24 hours; this not only diminishes the nutritive value of manure, but also creates a significant environmental problem.

Ammonia Considered A Major Pollutant

Ammonia is considered by the U.S. Environmental Protection Agency (EPA) a major air and water pollutant contributing to surface water eutrophication (too much nutrients stimulate excessive plant growth, which leads to oxygen depletion), soil acidity, and aerosol formation that can impair atmospheric visibility and human health. The effect on human health is mainly through formation of so-called fine particulate matter (PM2.5; particles with aerodynamic diameter less than or equal to 2.5 microns). When inhaled, these particles may contribute to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer. We estimated that, across different regions of the U.S. and depending on weather conditions, PM2.5 attributable to ammonia emitted from livestock operations is on average from 5 to 11 percent of the total PM2.5 concentrations.

Through wet or dry deposition as ammonium, volatilized ammonia can also contribute to water pollution. Atmospheric transport and fate of ammonia depend on meteorological chemical conditions. Models have predicted, for example, an average lifetime of atmospheric ammonia aerosol of 3 to 4 days. Thus, ammonia emitted from animal operation may impact water quality immediately or at considerable distance from the emission source. Some authors have estimated ammonium wet deposition in the Chesapeake Bay watershed at about 47 percent of the total inorganic nitrogen deposition.

Dietary protein is an important nutrient for maintenance and production of the animal and its deficiency leads to loss of production and poor animal health and reproduction. Protein requirements, however, may be over-predicted by the current dairy protein models leading to overfeeding of protein, deliberately through ration formulation, or due to inadequacy of monitoring of feeding management practices. As excess feed protein results in increased nitrogen losses with urine and ammonia volatilization losses from manure, it becomes critically important that producers do not overfeed protein so urinary nitrogen losses and ammonia volatilization are minimized.

Field Project Aimed at Reducing Farm Ammonia Emissions

Several trials at Penn State demonstrated that reducing dietary protein below current recommendations decreases ammonia losses from dairy manure by as much as 40 percent. Knowledge generated in these research trials was applied in the field through a NE Sustainable Agriculture Research and Education (NE SARE) grant aimed at reducing ammonia emissions from commercial dairy farms in Pennsylvania. The project included 12 small (50 cows) or larger (550 cows) free- or tie-stall cooperator dairies in Central, Southeast, and Southwest Pennsylvania with scrape, gravity-flow, or flush manure management systems. All dairies fed a total mixed ration (TMR). Throughout the project the research team performed extensive forage and TMR sampling to verify dietary protein levels. Background data for the high-protein feeding period were collected in Year 1 of the project and then dietary protein was reduced from an average of 16.5 (in Year 1) to 15.4 percent (Fig. 1) and data collection was repeated in Year 2 (low-protein period). Barn floor and laboratory manure ammonia emissions were measured twice, in spring and fall, before and after the reduction in dietary protein. Milk production of the cows and income-over-feed costs data were collected throughout the project.

Average ambient temperature during the low-protein period was much lower compared with the high-protein period (43 versus 57ºF, respectively) and although barn floor ammonia emissions were more than 50 percent lower during the low-protein period, the team was not able to attribute this decrease to the decrease in dietary protein alone due to the large difference in environmental temperatures. Samples of fresh manure collected from the dairies, however, were tested at Penn State and ammonia emission determined in controlled laboratory conditions was 23 percent lower during the low-protein period (see Fig. 2). Thus, the team was able to replicate in the field what has already been demonstrated at the university facilities.

We also investigated the effect of barn design and manure management on ammonia emissions. Our data showed that barn floor ammonia emissions were considerably lower for flush versus scrape and gravity-flow dairies (Fig. 3). The greatest methane (a potent greenhouse gas) emissions were observed for the gravity-flow dairies followed by scrape and flush manure systems.

Milk production was monitored throughout the project and was unaffected by the reduction in dietary protein: 70.8 and 71.5 for the high- and low-protein periods, respectively. Milk fat and protein content were also not different between the two periods. Income-over-feed cost was on average $6.75 for the high-protein period versus $7.37 for the low-protein period, an increase of $0.62 per cow, per day. Milk urea nitrogen concentrations tended to be lower during the low-protein feeding period (13.2 versus 14.5 mg/dL).

In conclusion, this on-farm project demonstrated that manure ammonia emissions can be significantly reduced on commercial Pennsylvania dairy farms by moderately decreasing dietary protein content without affecting milk yield and composition. The reduction in dietary protein can be beneficial for farm profitability (by decreasing feed costs) and will help the environment by reducing manure nitrogen losses and air pollution.

About the author:

Alexander N. Hristov, Associate Professor of Dairy Nutrition, joined the Department of Dairy and Animal Science faculty in 2008. He earned his Ph.D. and B.Sc. degrees in Animal Science in his native Bulgaria. Dr. Hristov was associate professor at the University of Idaho and worked with the Lethbridge Research Centre, Canada and with the US Dairy Forage Research Center in Madison, Wisconsin. His responsibilities include both research and teaching, with his research focused on ways to improve nitrogen utilization in the dairy cow and reduce the environmental impact of dairy operations.

Fig. 1. Dietary protein before and after reduction

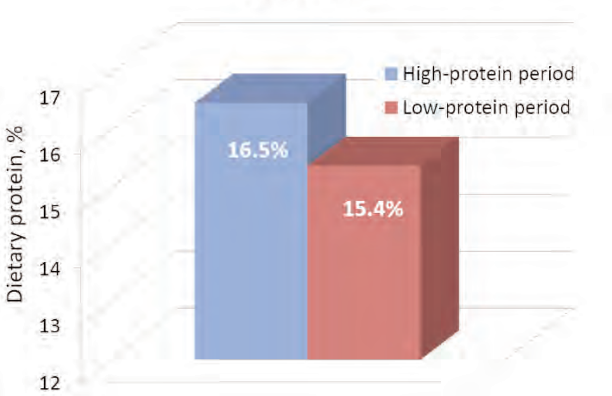


Fig. 2. Ammonia emissions from cow manure

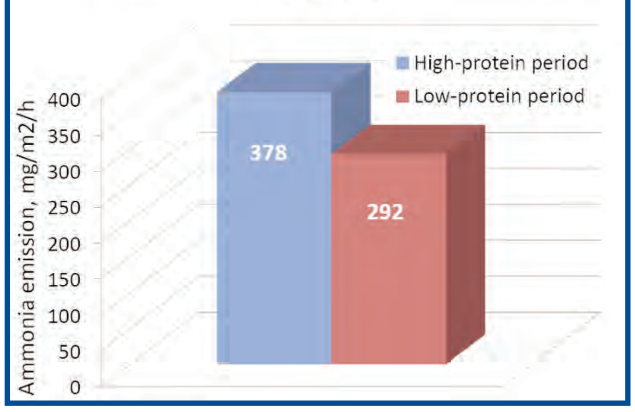
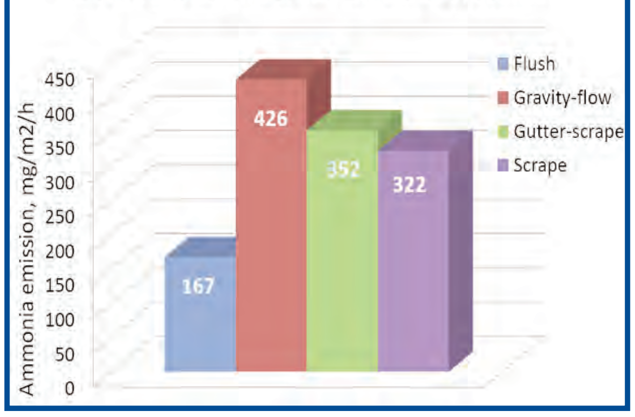


Fig. 3. Barn floor ammonia emissions from dairies with different manure systems



Penn State Dairy Resources on the Web:

Department of Dairy and Animal Science: www.das.psu.edu

College of Agricultural Sciences: www.agsci.psu.edu

Cooperative Extension: www.extension.psu.edu

Contact Information:
Department of Dairy and Animal Science
Pennsylvania State University
324 Henning Building • University Park, PA 16802
814-863-3665