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Effect of Dietary Crude Protein on Ammonia Emissions From Open-Lot Beef Cattle Feedyards

Syamalakumar Pandrangi, M.S. Graduate Student
West Texas A&M University, Canyon, Texas 79016 SKPandrangi@yahoo.com

David B. Parker, Ph.D., P.E., Associate Professor
West Texas A&M University, Canyon, Texas 79016 dparker@mail.wtamu.edu

L. Wayne Greene, Ph.D., Professor
Texas A&M University, Amarillo, Texas 79106 wgreene@tamu.edu

Lal K. Almas, Ph.D., Assistant Professor
West Texas A&M University, Canyon, Texas 79016 lalmas@mail.wtamu.edu

Marty B. Rhoades, Research Associate
West Texas A&M University, Canyon, Texas 79016 mrhoades@mail.wtamu.edu

N. Andy Cole, Ph.D., Research Animal Scientist
USDA-ARS, CPRL, Bushland, Texas 79012 nacole@cprl.ars.usda.gov

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Abstract. *A laboratory study was performed to compare ammonia emissions from simulated feedlot surfaces. Beef cattle manure was collected from open lot pens at the USDA-ARS feedlot in Bushland, TX. Treatments within the pens consisted of two dietary crude protein concentrations (11.5 and 13%) and two protein sources (urea and cottonseed meal). Manure collected from the pens was placed into Tupperware® chambers in the laboratory. Chambers were sealed and ammonia was trapped in an acid solution for 15 days using a vacuum system. Results suggest that* *as the protein concentration in the diet increases, potential daily ammonia emissions increase. The source of crude protein had little effect on ammonia emissions.*

Keywords. Ammonia, emissions, beef cattle, feedlot, feedyard, air quality, crude protein, urea, cotton seed meal.

Introduction

Cattle production is the principal animal agricultural operation in the Texas Panhandle area. More than seven million cattle are fed each year in the area (SPS, 1999). There are 70 feedyards in the area with capacities greater than 20,000 head (Parker et al., 1997). Major concerns to cattle producers in this region are manure management and nutrient accumulation. In a typical open lot beef cattle feedyard, manure is left on the pen for 120 to 365 days before removal. During this time manure starts drying and much of the N is lost through ammonia volatilization. The loss of N to the atmosphere can decrease the nitrogen:phosphorus (N:P) ratio in the manure and lead to adoption of phosphorus-based manure application. According to Shi et al. (2001), imports from purchased feeds are greater than nutrient exports. This might lead to nutrient accumulation.

Ammonia emissions from feedlot manure have become a major environmental concern because of its numerous effects on air quality. Intensive livestock operations can create a significant source of ammonia emissions in the atmosphere, as has been documented in several studies. These emissions may impact the surrounding ecosystem and their use (Arogo et al., 2001). Ammonia and oxides of N and S are considered as potential contributors to secondary particulate matter, especially PM10 and PM2.5 (Morse, 1996a; Morse, 1996b). Volatilized ammonia tends to be oxidized by various oxidants in the air to produce nitrous oxides, which are widely recognized as being major contributors to acid rain. Studies in Europe consistently find that measures to reduce ammonia generally reduce odors for other compounds as well (Xue et al., 1998). Decreasing the ammonia emissions can not only decrease the environmental pollution but also increase the fertilizer value of the manure. Hence, efforts to minimize ammonia emissions are warranted. Many countries in Europe have regulations limiting the quantities of ammonia emissions from CAFOs. However, there are few regulations in the United States limiting odor emissions. Ammonia emissions may be regulated in the future.

Ammonia is generated from animal housing and manure storage facilities of feedlots due to volatilization of manure nitrogen. Emissions may also appear after the field application of manure. The sources of ammonia gas in the feedlot are animal feces and urine. Urine contains 70-80% of the total excreted nitrogen and 99% of the dry weight of the urine is urea (Shi et al., 2001).

Mechanisms for Ammonia Emission Reduction

Minimizing ammonia emissions requires a whole system approach. The strategies should be directed towards minimizing ammonia volatilization, ammonia formation and manure N excretion. Cattle producers can minimize ammonia emissions in a number of ways. Proper manure management and treatment techniques can decrease the emissions. In open lot feedyards, soil amendment techniques may be effective in reducing the emissions (Shi et al., 2001). Another important technique is diet modification. Many other methods can reduce emissions, but all methods are not practical or economically feasible.

Efficiency of dietary N is up to 15 percent of the total N in the diet, and the remaining amount is lost through excretion. Bierman et al. (1995) indicated that scientists have estimated as much as 50% of feed N is lost as ammonia. Diet change can be used as a technique in minimizing ammonia emissions since composition of the diet can influence the quantity and chemical composition of the manure produced. The idea behind this practice is to produce less N in the excreted manure so that there can be fewer emissions. At present, 13.5% of crude protein is fed in commercial feedyards throughout the feeding period. This is not in accordance with the protein requirements of the animal. The protein requirements are higher in younger animals and less before harvest. The adult ruminant animal can produce significant amounts of its protein requirement from non-protein nitrogen sources by microbial growth in the stomach. The technique of feeding a higher nitrogen percentage to calves in early stages and decreasing the amount later as the animal matures, according to the protein requirements of the animal, may decrease the unnecessary N supply to the animal.

The nitrogen produced in the manure may also depend on the type of crude protein source. The protein source for the beef cattle comes from natural plant proteins from non protein nitrogen (NPN). Ingested natural protein may either be degraded by the bacteria in the stomach (60%) or may escape the degradation (40%) and be absorbed by the animal (Satter and Rofler, 1977). The rumen microorganisms utilize ammonia produced from the degraded protein and NPN to produce microbial protein, which is absorbed into the blood. Urea produced from NPN and not utilized by the microbes, and any unutilized ammonia is excreted through urine. Urea is the most commonly used NPN. Cotton seed meal (CSM) is a natural plant protein that is more soluble and more hydrolyzed in the rumen, and thus is a suitable substitute for urea (Stanton, 1998). The use of the natural protein and NPN will have different digestive cycles and can have different amounts of N in the manure. In designing the diet for minimizing N excretion, one should consider the source of the crude protein and the percentage of N in the diet. Difference in the prices of the crude protein source can bring savings to the farmer. Using non-protein nitrogen sources like urea might decrease the protein costs (Cole et al., 1996). The feeding techniques not only provides environmental protection, but also provides economic benefits because the cost of feed will be less for less N fed.

Research was conducted to study the ammonia emissions from the manure of the beef cattle that were fed 2 different protein concentrations and 2 different protein sources. The objectives of the study were to determine if ammonia emissions could be reduced by altering crude protein concentrations or crude protein sources.

Materials and Methods

A laboratory experiment was conducted to analyze the effect of alternative feeding management techniques in minimizing ammonia emissions. Beef cattle manure was collected from the open lot pens of a nutrient balance trial condected at the USDA- ARS research feedlot in Bushland, TX. The cattle were fed two crude protein concentrations of 11.5 and 13.0%, and two crude protein sources of urea and cotton seed meal, for a total of four treatment combination. Each treatment combination was assigned to three pens, for 12 pens total. Manure collected at the end of the feeding period was used in air emission chambers to compare volatile ammonia emission.

Six treatments were used with six chambers per treatment

1. Blank (no soil and no manure)
2. Control (soil without manure)
3. Manure collected from cattle fed an 11.5% crude protein diet, with urea as the protein source.
4. Manure collected from cattle fed an 11.5% crude protein diet, with cotton seed meal as the protein source.
5. Manure collected from cattle fed an 13.0% crude protein diet, with urea as the protein source.
6. Manure collected from cattle fed an 13.0% crude protein diet, with cotton seed meal as the protein source.

Six manure samples from each treatment were collected, three from the front end of the three pens (just below the apron) and three near the back of the three pens (near the water trough). The initial moisture content of each manure sample was measured by oven drying at 100°C for 24 hrs. A total of 36 containers were used as in-vitro air emission chambers. Each Tupperware® container had dimensions of 16.7 x 16.7 x 17 cm height. The chambers were filled with 5.1 cm of soil. The manure samples were chipped into small pieces of diameter less than 1 cm and were placed 5.1 cm thick on top of the soil to simulate the feedlot conditions. The soil used was Pullman clay loam collected from the field of USDA-ARS Conservation and Production Research Laboratory in Bushland, TX. Each chamber was connected to a bottle containing 100 ml of 0.9 M sulfuric acid (acid trap). The acid traps were connected to a common plastic container to ensure an equal airflow from all the chambers (Fig. 1). The common container was then connected to the vacuum pump (Marathon Electric, Model No 80M48S17D1180JP, 1/3 Hp, 115 volt, 75 L/min max.). The ambient air above the manure from each container was pulled through the acid traps into the common container by the vacuum pump. An airflow rate of 53 L/min was maintained using the flow meter, for an airflow of 1.47 L/min per container. The ammonia was trapped in the sulfuric acid of the acid trap. Acid traps were analyzed for total nitrogen content by automated procedures at the USDA-ARS Conservation and Production Research Laboratory in Bushland, TX. The acid traps were changed every 24 hours for the first week and every 48 hours for the second week and a total of 11 observations were obtained. On day seven, 270 ml of water was added to each chamber to adjust for evaporation losses and determine how water addition affected ammonia emissions.

Statistical Analysis

The daily average emissions of each chamber were obtained and compared to test the effect of each treatment. A 2x2 factorial design was used with 2 CP concentrations (11.5 and 13%) and 2 CP sources (urea and CSM). In addition, Tukey's HSD test was used to compare all six treatments including the blank and control.

Results and Discussion

Both 13% protein treatments had higher ammonia emission rates than the 11.5% protein treatments (Table 1, Fig. 2). There was little difference between the urea and CSM treatments for the 11.5% protein, but for the 13% protein the urea had a higher ammonia emission rate than the CSM.

The 2x2 factorial analysis indicated that there was a significant difference between the 11.5 and 13% protein concentrations (P=0.03). However, there was no difference between the emissions for the urea and CSM sources of protein (P=0.26). Linear contrasts between protein concentrations within individual protein sources indicated a significant difference for urea (P=0.008) but not for CSM (P=0.35). Contrasts between protein sources within protein concentrations indicated a borderline difference for the 13% protein (P=0.08) but none for 11.5% protein (P=0.88). The same conclusions were obtained using Tukey's HSD test (Table 1).

Some of the variation in the emissions within the treatments and replications may be due to the difference in the initial moisture content of the manure samples as collected within the pens. Initial moisture contents varied greatly, with a range of 20 to 80%. There was a significant positive correlation between ammonia emissions and initial moisture content (r=0.55, P=0.005) (Fig. 3).

The analysis of the data suggests that as the nitrogen concentration in the diet supplied to the animal decreases, the ammonia emissions also decrease. The lower the nitrogen in the feed supplied to the animal, the lower the nitrogen in the manure, thereby reducing ammonia emissions. At the 13% protein concentration, ammonia emissions were higher when urea was used as a crude protein source. The source of the crude protein supplied to the animal had no effect on the emissions at the 11.5% protein concentration. These results suggest it can be possible to reduce emissions with a modified feeding technique supplying less feed N. The decrease in feed N could potentially save feed costs also. By analyzing the fresh manure, additional information could be learned about the treatments. There are experimental constraints in collecting the fresh manure from each animal for all the treatments, and these constraints prohibit representing true feedlot conditions. The health and performance of the animal should be considered before using the feeding technique in minimizing the emissions.

Ammonia emission rates decreased during the first 7 days of the experiment in all the treatments (Fig. 2). The addition of water on day 7 appeared to increase the ammonia emissions slightly for 4 to 6 days for the two urea treatments. A very slight increase was observed for 2 days for the cotton seed meal treatments.

The 15-day average ammonia emission rates ranged from 546 to 1172 µg/(m^2•min). This is about one-third of the 21-day average emission rate of 3307 µg/(m^2•min) measured in a similar laboratory study when fresh feces and urine were used (Shi et al., 2001).

Conclusions

This research demonstrated that a lower protein diet results in less ammonia volatilized. Little difference in ammonia concentrations were observed between the two protein sources of urea and cottonseed meal. This research shows that use of a diet management technique can decrease the ammonia emissions. Animal health and performance should be considered before using this technique.

Readers are urged to be careful before using this emission data to develop emission standards from beef cattle feedyards. The daily emissions may be less than would be found in a commercial feedyard setting because aged manure (manure at the end of the feeding period) was used in the experiment. In a typical feedyard, feces and urine are deposited on the ground daily. In this research project, because feces and urine were not added daily, it is probable that the emission rates measured in this experiment do not represent actual field conditions.

Table 1. Mean ammonia emission rates μg/(m^2•min) over the 15 day study by treatment. Each mean is calculated from six replications.

Treatment	Mean	Std. Dev.	Minimum	Maximum
Blank	2.9a	0.4	2.4	3.5
Control (soil only)	2.5a	0.6	1.8	3.1
11.5% CP, Urea	546b	260	236	925
11.5% CP, CSM	578b	188	350	887
13.0% CP, Urea	1172c	367	731	1700
13.0% CP, CSM	784bc	557	396	1897

Means within a column with different letters are significantly different using Tukey's HSD test at α=0.05.

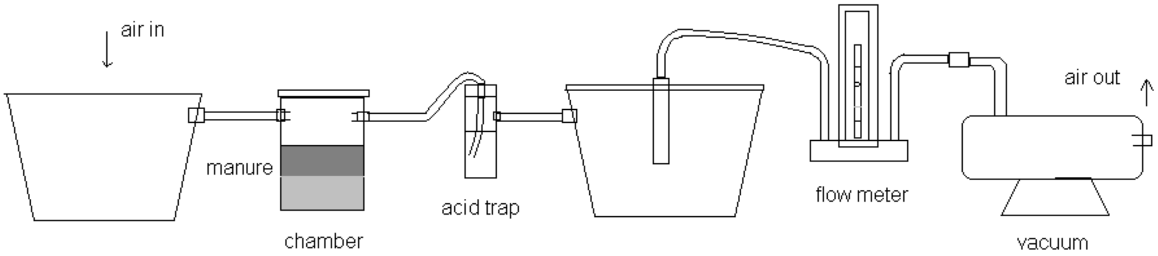

Figure 1. Schematic of the apparatus used to measure ammonia emissions from simulated feedyard surfaces.

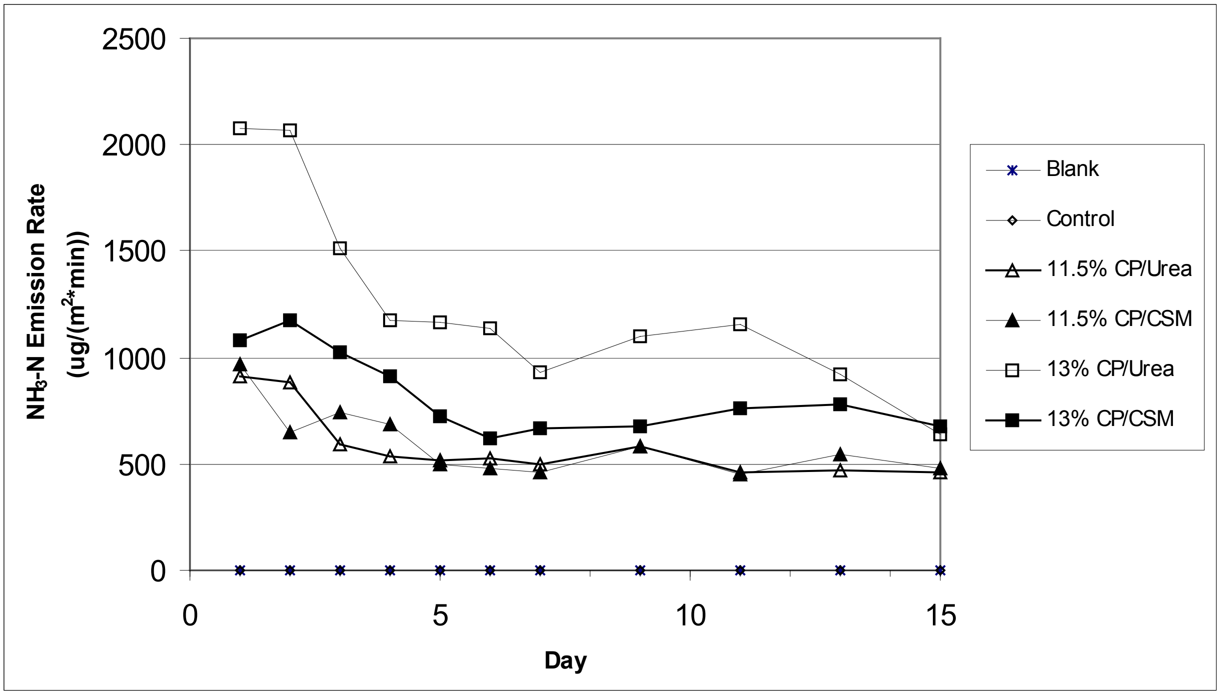

Figure 2. Plot showing how daily ammonia emission rates varied over the 15-day study period. Water was added on day 7. Each data point is the mean of six replications.

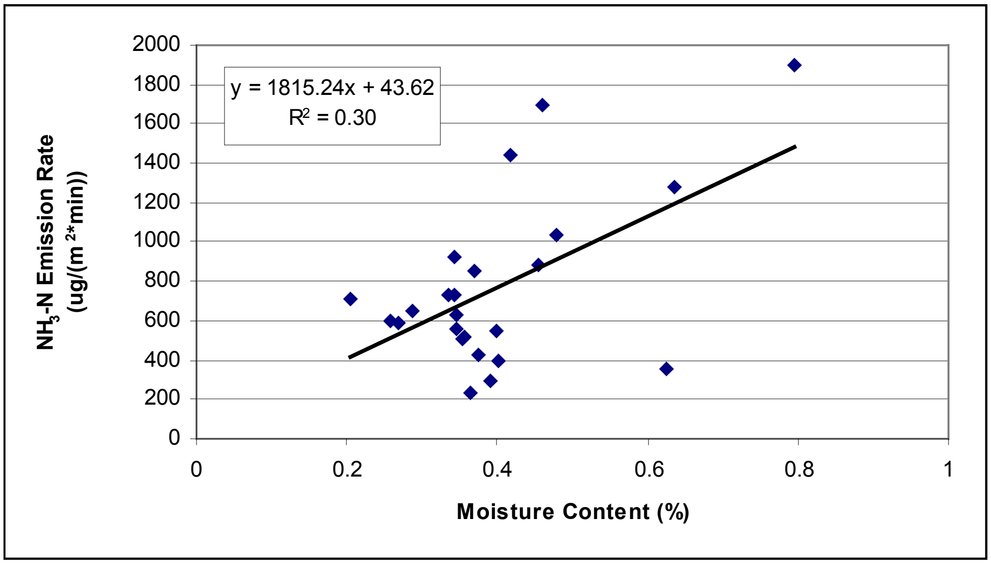

Figure 3. Plot showing how 15-day average daily ammonia emission rates varied with the initial moisture content of the manure.

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