This is not a peer-reviewed article.
International Symposium on Air Quality and Waste Management for Agriculture. CD-Rom Proceedings of the 16-19 September 2007 Conference (Broomfield, Colorado)
Publication date 16, September 2007
ASABE Publication Number 701P0907cd

Use of Fat and Zeolite to Reduce Ammonia Emissions from Beef Cattle Feedyards

N. A. Cole, R. W. Todd, and D. B. Parker

USDA-ARS-CPRL, Bushland, TX, and West Texas A&M Univ., Canyon

Abstract. Ammonia emissions from cattle feedyards may comprise 40% or more of nitrogen intakes. Decreasing ammonia emissions would improve the fertilizer value of feedyard manure and decrease potential adverse effects on the environment. Two trials were conducted to evaluate the effects of fat and zeolite on potential ammonia emissions from a feedlot surface. In the first trial corn oil, alum, a urease inhibitor, or potassium zeolite were added to simulated feedlot surfaces in lab-scale chambers and ammonia losses were captured using an acid solution. In trial two, five beef steers were fed one of five finishing diets (0% added fat, 3% added fat, 6% added fat, 3% fat+1% zeolite, or 3% fat+2% zeolite) in a 5 x 5 Latin square. During the last 5 days of each period feces and urine output were collected in stalls to determine nutrient digestion and retention. Feces and urine from each steer were used in the lab-scale flow-through chambers to estimate potential ammonia losses. In trial 1, zeolite and fat additions decreased ammonia losses by 51 to 86%; however the effects were not additive. In trial 2, apparent protein digestion, nitrogen retention, and nitrogen excretion were not affected by dietary fat or zeolite. In vitro ammonia losses were not significantly affected by dietary zeolite; however in vitro ammonia losses were greater ($P < 0.05$) when steers were fed diets containing no added fat. These results suggest that fat and zeolites can potentially decrease ammonia emissions from beef cattle feedyards.

Keywords. Ammonia, beef cattle, feedlot, fat, zeolite

Introduction

Beef cattle producers face increased concerns about effects of agricultural practices on the environment. Significant quantities of nutrients such as nitrogen (N) can be lost to the environment by volatilization from urine and feces on the pen surface. Approximately 80 to 90% of the N fed to beef cattle is subsequently excreted in the feces and urine. From 25 to 60% of excreted N can volatilize from the feedlot surface, primarily as ammonia (NH_3-N), and contribute to air quality concerns (Hutchinson et al., 1982; Todd et al., 2005; Cole et al., 2005). Losses of ammonia from the feedlot pen surface are dependent on factors such as surface pH, ammonia+ammonium (NH_x-N) concentration, and environmental conditions as well as dietary factors that affect fecal or urine pH or the urinary excretion of N. Pen surface amendments such as alum, zeolite, and urease inhibitors have the potential to decrease emissions of ammonia (Varel et al., 1999; Lefcourt and Meisinger, 2001; Shi et al., 2001; Eng et al., 2003; Parker et al., 2005). Although results are somewhat inconsistent, some studies suggest the feeding of zeolites may improve animal performance and reduce N losses from manure (Eng, et al., 2003). However, adsorption sites on zeolites may be tied up by ammonia in the digestive tract and thus limit the capacity of excreted zeolites to bind ammonia on the pen surface. Fat is often added to feedlot diets to increase the energy density of the diet and to reduce "fines" in the feedbunk, but the effects of fat on ammonia emissions is not known.

The objectives of these studies were to 1) use a laboratory-scale *in vitro* system to measure effects of dietary supplementation or pen surface amendments of fat and zeolite on losses of ammonia from beef cattle feces and urine, and 2) evaluate the effects of dietary amendments of fat and zeolite on animal nutrient metabolism.

MATERIALS AND METHODS

Experiment 1: Pen Surface Amendment

The potential effects of fat and (or) zeolite additions to the feedlot pen surface on potential ammonia losses were estimated using an in vitro ammonia system previously described (Shi et al., 2001: Cole et al., 2005). Briefly, soil (1550 g) was added to hermetically sealed plastic chambers (20 cm x 20 cm x 12 cm) constructed with inlet and outlet valves. Appropriate amendments were added and mixed with the soil. Two hundred grams of a blend (67 g & 133 g, respectively) of fresh beef cattle feces and urine collected from 5 steers confined to tie stalls were added, mixed with the soil, and the chambers were sealed. Air was continuously passed through each chamber and ammonia was collected in traps containing 0.9 M sulfuric acid. Subsamples of soil, feces, and urine were analyzed for N, C, pH, NHx-N, and NOx-N.

The following soil amendments were tested with three chambers per treatment:

1. Soil blank – 1,550 g soil with no added manure,
2. Positive Control = soil blank + 200 g of the feces and urine mixture,
3. Positive control + 18 g Alum (equal to 4,500 kg/ha),
4. Positive control + 36 g Alum (equal to 9,000 kg/ha),
5. Positive control + 9 g of zeolite (equal to 2,250 kg/ha)
6. Positive control + 18 g of zeolite,
7. Positive control + 36 g of zeolite,
8. Positive control + 18 g of corn oil,
9. Positive control + 36 g of corn oil,
10. Positive control + 18 g of alum and 18 g of zeolite,
11. Positive control + 18 g of alum and 18 g of corn oil,
12. Positive control + 9 g of alum, 9 g of zeolite and 18 g of corn oil,
13. Positive control + 1 g of the urease inhibitor N-(n-butyl)thiophosphoric triamide (NBPT)(equal to 250 kg/ha)
14. Positive control + 1 g of NBPT + 18 g of zeolite.

Data were statistically analyzed by analysis of variance using the General Linear Models procedure of SAS (1990). Chamber was considered the experimental unit.

Trial 2 Dietary Amendment – Digestion and *In vitro* Ammonia Loss

All procedures were approved by the animal care and use committee of the Cooperative Research , Extension and Education Team.

Five crossbred steers (average body weight = 315 kg) were randomly assigned to one of five finishing diet treatments in a 5 x 5 Latin square design. Dietary treatments consisted of the following: 1) 0 % fat, 2) Control 3% fat, 3) 6% fat, 4) Control + 1% zeolite, and 5) Control + 2% zeolite (Table 1). During the feces and urine collection periods, steers were individually confined in tie stalls and were fitted with urine collection harnesses. On the first day of collection, fresh feces and unacidified urine were obtained for the *in vitro* ammonia emission portion of the study. To determine N and P excretion, feces and urine were collected, weighed, sampled, and composited for a 5-d period. Feed, urine and feces samples were analyzed for dry matter, N, C and pH (AOAC, 1990).

Table 1. Composition of diets fed to steers in nutrient balance experiment (% dry matter basis, unless shown)

Item	0% fat	3% fat	6% fat	1% zeolite	2% zeolite
Corn, steam flaked	80.3	76.3	73.3	75.3	74.3
Soybean hulls	10.0	10.0	10.0	10.0	10.0
Cottonseed meal	2.18	3.18	3.18	3.18	3.18
Molasses	4.0	4.0	4.0	4.0	4.0
Fat blend	0	3.0	6.0	3.0	3.0
Zeolite	0	0	0	1.0	2.0
Urea	1.2	1.2	1.2	1.2	1.2
Supplement[1]	2.32	2.32	2.32	2.32	2.32

Chemical component [2],					
Crude protein, %	13.3	13.4	13.2	13.3	13.2
DIP, %	8.94	9.04	8.94	9.00	8.96
NEg, Mcal/kg	1.40	1.44	1.49	1.43	1.41

[1] Supplement contained macro- and micro-minerals, vitamins A and E, Tylan and Rumensin (Elanco Animal Health, Indianapolis, IN).

[2] Crude protein is analyzed value. DIP = degraded intake protein and NEg = net energy for gain calculated from NRC (2000).

The *in vitro* ammonia emission system used was essentially the same as for the first experiment. However, rather than adding a constant amount of a standard feces and urine mixture, the quantity of feces added to each chamber was equal to 2% of the daily excretion by one steer during the nutrient balance trial and the quantity of urine added was equal to 1% of the daily excretion by one steer, with 3 chambers per steer.

Data for the digestion trial and in vitro ammonia emission trial were analyzed as a 5 x 5 Latin square design using the GLM procedure of SAS (SAS 1990). Steer was the experimental unit for all statistical analyses. Factors included in the model were steer, dietary treatment, and period of the Latin square. Dietary treatment effects were tested using PDIFF procedure if a significant ($P < 0.05$) F-test was obtained.

RESULTS AND DISCUSSION

Trial 1 Surface Amendments

All pen surface amendments significantly decreased *in vitro* ammonia losses from the simulated feedlot surfaces by 49% or more (Table 2). The greatest inhibition of ammonia losses occurred with the corn oil treatments. Combining zeolite with alum or NBPT seemed to have an additive or synergistic effect. Alum, zeolite and NBPT inhibit ammonia losses via different methods (acidifying effect, adsorption, or prevention of hydrolysis of urea to ammonium, respectively). The mechanism by which corn oil decreased ammonia losses is not clear; although the pH of the soil-manure mixture was lower in the corn oil treatments. The oil could have an inhibitor effect on microbial activity or could tie up the ammonia physically or chemically.

Shi et al. (2001) and Parker et al. (2005) noted a similar response to NBPT. However, Parker et al. (2005) noted that the effects of NBPT were transient and suggested that NBPT would have to be applied at least every 8-days to continue to inhibit ammonia losses. Lefcourt and Meisinger (2001) noted that zeolite additions to dairy waste slurry decreased cumulative ammonia losses by 22 (2.5% zeolite) to 47% (6.25% zeolite). Bernal and Lopez-Real (1993) reported that the ammonium adsorption capacity of zeolites ranged from 8.1 to 15.2 mg N per g. Thus, it is probable that zeolites, as well as other pen surface amendments, will need to be added to the pen surface at intervals, once the adsorption sites were occupied by ammonium/ammonia.

Table 2. Effects of pen surface amendments on ammonia losses, and pH of simulated feedlot pen surface using an *in vitro* system

Treatment	NH_3-N, mg/14 days [a]	NH_3-N, % decrease [a]	Final pH
Positive control	90.92	--	7.53
Alum, 18 g	44.97	50.5	6.57*
Alum, 36 g	22.42	75.3	5.66*
Zeolite, 9 g	43.02	52.7	7.87
Zeolite, 18 g	44.60	49.0	8.02
Zeolite, 36 g	29.89	67.1	8.14
Corn oil, 18 g	16.19	82.1	6.65*
Corn oil, 36 g	10.82	88.1	6.83*
Alum + zeolite	25.80	71.6	7.41
Alum + corn oil	14.80	83.7	7.37
Alum + zeolite + corn oil	16.44	81.9	7.28
NBPT	38.31	57.9	8.05
NBPT + zeolite	21.43	76.4	8.04
SEM	3.81	4.19	0.14

[a] All treatment means were significantly different from the positive control at $P < 0.001$ or greater. * Significantly different from positive control, $P < 0.01$.

He et al. (2002) noted that a combination of cellulose and zeolite had a greater effect on ammonia losses from urea application to soils than either compound alone, possibly as a result of increased microbial uptake of ammonia. Similarly, Kithome et al. (1998) noted that slow rates of ammonia emission could render zeolites more effective at adsorbing ammonium because of the longer time for contact between the ammonium and zeolites. Thus, slowing the release of ammonium via addition of a urease inhibitor or fermentable cellulose could make zeolites more efficient at ammonium adsorption.

The final pH of the soil–manure media was lower ($P < 0.01$) for the alum and corn oil treatments than the control or other treatments. The lower pH on the alum treatment was expected because of the acidifying effect of alum. However, the cause for the lower pH of the corn oil treatments is less apparent. It might be caused by production of acids via microbial fermentation of the corn oil or of carbohydrates in the manure, or by binding of basic compounds such as bicarbonate.

Trial 2 - Dietary Amendments – Digestion and In vitro Ammonia Loss

Supplementing the finishing diets with fat or zeolite did not significantly affect dry matter intake or dry matter digestibility (86.4% $\pm$ 2.1), however, on average, steers fed the 6% fat and 2% zeolite diets had numerically lower dry matter intakes than the remaining treatments (Table 3). Fecal and urinary N excretion tended to differ among diets however N digestion was not significantly affected by dietary treatment. Nitrogen balance was greater for the 3% fat diet than the 0% or 6% fat diets. Nitrogen balance of steers fed the 3% fat diets containing zeolite was not significantly different from steers fed the 3% fat control diet. The N:P ratio of feces, urine and feces+urine and P metabolism were not significantly affected by diet (data not shown).

Addition of zeolites to ruminant diets has had inconsistent effects on animal performance, ruminal metabolism, and nutrient excretion (Galyean and Chabot, 1981; McCollum and Galyean, 1983; Eng et al., 2003; Sherwood et al., 2006). The effects of fats on nutrient metabolism have not been studied extensively. Somewhat in agreement with our results, Zinn and Plascencia (1996) noted that fecal N excretion was lower and crude protein digestion was greater in steers fed 6% fat diets than in steers fed no supplemental fat.

Table 3. Nitrogen metabolism of steers fed experimental diets containing differing concentrations of fat and 3% fat plus zeolite

Item	0 % fat	3 % fat	6 % fat	1% zeolite	2% zeolite	SEM
Dry matter intake, g/d	6,920	7,280	6,496	7,389	6,414	251
Nitrogen intake, g/d	144.4^{a}	149.6^{a}	126.3^{b}	150.4^{a}	127.5^{b}	5.34
Fecal N excreted, g/d	40.7^{a}	29.3^{b}	34.8^{ab}	36.2^{ab}	29.0^{b}	5.49
Urine N excreted, g/d	70.9^{a}	55.3^{b}	57.9^{b}	56.7^{b}	46.8^{b}	5.31
Nitrogen digestion, %	74.1	79.2	73.3	75.9	76.9	3.72
N balance, g/d	33.6^{c}	65.0^{d}	33.7^{c}	57.4^{cd}	51.7^{cd}	7.19

[ab] Means in same row without a common superscript letter tend to differ ($P < 0.10$).
[cd] Means in same row without a common superscript letter differ ($P < 0.05$).

By design, the quantity of fecal, urine, and total N added to the *in vitro* ammonia chambers was proportional to N excreted by the steers (Table 4). Urine pH was lower in steers fed the 2% zeolite diet than the remaining diets. In cattle fed high concentrate diets ammonia may serve as a systemic buffer via uptake of free H^+ and subsequent excretion of urea in the urine. If zeolites adsorb a considerable quantity of ammonia in the digestive tract, less ammonia may be absorbed from the rumen and become available to serve as a systemic buffer; thus, urinary pH could decrease.

Total gaseous NH_3-N loss was greater for the 0% fat diet than the remaining diets. This was partially due to greater N additions to the chambers, but was also due, in part, to loss of a greater proportion of the N added. The quantity of N in the form of soil NH_x-N was also greater for the 0% fat diet. In steers fed the 0% fat diet approximately 95.5% of added N was lost as ammonia or accumulated as NH_x-N in the soil. This was almost 2x the percentage in the remaining treatments. Addition of zeolite to the 3% fat diet did not further decrease ammonia losses. In contrast to our results, Eng et al (2003) noted that addition of zeolite to the diet of finishing beef cattle had a greater effect on reducing ammonia emissions than additions directly to the manure.

Table 4. Effects of fat or zeolite in the diet on cumulative ammonia N loses from the *in vitro* chambers and N changes in the chamber over 7-d.

Item	0% fat	3% fat	6% fat	1% zeolite	2% zeolite	SEM
Feces N added, mg	814^{b}	586^{a}	696^{ab}	724^{ab}	580^{a}	54.9
Urine N added, mg	709^{b}	553^{a}	579^{a}	567^{a}	468^{a}	53.1
Added N, mg	1,523^{d}	1,139^{c}	1,275^{cd}	1,291^{cd}	1,048^{c}	85.6
Urine pH	8.77^{c}	8.74^{c}	8.57^{cd}	8.84^{c}	8.37^{d}	0.07
NH_3-N lost, mg	853^{d}	271^{c}	323^{c}	245^{c}	211^{c}	54.1
NH_3-N lost, % of total N	56.0^{d}	23.8^{c}	25.3^{c}	19.0^{c}	20.1^{c}	6.9
NH_3-N lost, % of urine N	120.3^{d}	49.0^{c}	55.8^{c}	43.2^{c}	45.1^{c}	13.4
Ending soil NH_x-N, mg	597^{d}	296^{c}	279^{c}	254^{c}	235^{c}	29.9
NH_3-N + NH_x-N, mg	1,450^{d}	568^{c}	602^{c}	499^{c}	447^{c}	61.3
NH_3-N + NH_x-N, % of added N	95.5^{d}	50.1^{c}	47.5^{c}	38.7^{c}	42.6^{c}	14.0
Ending C, % of DM	1.55	1.57	1.55	1.61	1.50	0.04

^{ab} Means in same row without a common superscript letter tend to differ ($P < 0.10$).

^{cd} Means in same row without a common superscript letter differ ($P < 0.05$).

Conclusion

Based on lab-scale studies, a number of pen surface amendments such as alum, zeolites, urease inhibitors, and corn oil appear to have the potential to reduce ammonia emissions from feedlot pen surfaces. However, additional larger scale studies are needed to confirm these results and to develop best management practices for these additives. Although zeolites decreased ammonia emissions when applied as surface amendments, when fed they did not affect animal N metabolism or potential ammonia losses. Feeding 3% fat appeared to decrease ammonia losses due to a combination of less urinary N excretion and a lower percentage of applied N being lost as ammonia. When fed, the ammonia binding sites on the zeolites may be occupied and thus may not be available for ammonia adsorption after excretion. In contrast, a proportion of the fat fed is undigested and excreted in feces and thus may be capable of reducing ammonia loses from the pen surface.

Acknowledgements. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

References

AOAC. 1990. Official Methods of Analysis. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Bernal, M. P., and J. M. Lopez-Real. 1993. Natural zeolites and sepiolite as ammonium and ammonia adsorbent materials. Bioresource Tech. 43:27-33.

Cole, N. A., R. N. Clark, R. W. Todd, C. R. Richardson, A. Gueye, L. W. Greene, and K. McBride. 2005. Influence of dietary crude protein concentration and source on potential ammonia emissions from beef cattle manure. J. Anim. Sci. 83(3):722-731.

Eng, K. S., R. Bectel, and D. P. Hutcheson. 2003. Adding a potassium, clinoptilolite zeolite to feedlot rations to reduce manure nitrogen losses and its impact on rumen ph, E. coli and performance. Proc 18th Southwest Nutr. and Mgt. Conf. Tempe AZ. Pg 15-25 http://animal.cals.arizona.edu/swnmc/papers/2003/eng.pdf (accessed 11-21-2006)

Galyean M. L., and R. C. Chabot. 1981. Effects of sodium bentonite, buffer salts, cement kiln dust, and clinoptilolite on rumen characteristics of beef steers fed a high concentrate diet. J. Anim. Sci. 52 (5):1197-1204.

He, Z. L., D. V. Calvert, A. K. Alva, Y. C. Li, and D. J. Banks. 2002. Clinoptilolite zeolite and cellulose amendments to reduce ammonia volatilization in a calcareous sandy soil. Plant and Soil. 247:253-260.

Hutchinson, G. L., A. R. Mosier, and C. E. Andre. 1982. Ammonia and amine emissions from a large cattle feedlot. J. Environ. Qual. 11:288-293.

Kithome, M, J. W. Paul, L. M. Lavkulich, and A. A. Bomke. 1998. Kinetics of ammonium absorption and desorption by the natural zeolite clinoptilolite. Soil Sci. Soc. Amer. J. 62:622-629.

Lefcourt, A. M., and J. J. Meisinger. 2001. Effect of adding alum or zeolite to dairy slurry on ammonia volatilization and chemical composition. J. Dairy Sci. 84; 1814-1821.

Mason, A. 2004. Nitrogen distribution in pen surface layers of beef cattle feedyards. MS Thesis. West Texas A&M Univ., Canyon.

McCollum, F. T., and M. L. Galyean. 1983. Effects of clinoptilolite on rumen fermentation, digestion and feedlot performance in beef steers fed high concentrate diets. J. Anim. Sci. 56 (3):517-524.

Parker, D. B., S. Pandrangi, L. W. Greene, L. K. Almas, N.A. Cole, M. B. Rhoades, and J. A. Koziel. 2005. Rate and frequency of urease inhibitor application for minimizing ammonia emission from beef cattle feedyards. Trans. ASAE 48(2):787-793.

SAS. 1990. SAS User's Guide: Statistics. V. 6a, Cary NC.: SAS Institute, Inc.

Sherwood, D. M, G. E. Erickson, and T. J. Klopfenstein. 2006. Nitrogen mass balance and cattle performance of steers fed clinoptilolite zeolite clay. 2006 Nebraska Beef Report, pg 90-91.

Shi, Y., D. B. Parker, N. A. Cole, B. W. Auvermann, and J. E. Mehlhorn. 2001. Surface amendments to minimize ammonia emissions from beef cattle feedlots. Trans. Am. Soc. Agric. Eng. 44(3):677-682.

Todd, R. W., N. A. Cole, L. A. Harper, T. K. Flesch, and B. H. Baek. 2005. Ammonia and gaseous nitrogen emissions from a commercial beef cattle feedyard estimated using the flux-gradient method and N:P ratio analysis. *In* P. J. Nowak (ed.) Proc. State of the Science: Animal Manure and Waste Management, National Center for Manure and Animal Waste Management, San Antonio, TX 5-7 Jan, 2005. Available at http://www.cals.ncsu.cdu/wastc_mgt/natlcneter/sanantonio/Todd.pdf (assessed 16 Nov. 2006). North Carolina State Univ., Raleigh.

Varel, V. H., J. A. Nienaber, and H. C. Freetly. 1999. Conservation of nitrogen in cattle feedlot waste with urease inhibitors. J. Anim. Sci. 77:1162-1168.

Zinn, R. A., and A. Plascencia. 1996. Effects of forage level on the comparative feeding value of supplemental fat in growing-finishing diets for feedlot cattle. J. Anim. Sci. 74:1194-1201.