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Effect of Feeding Distillers' Grains on Dietary Crude Protein and Ammonia Emissions from Beef Cattle Feedyards

R.W. Todd[1], N.A Cole[1], D.B. Parker[2], M. Rhoades[2], and K. Casey[3]
[1]USDA-ARS Conservation and Production Research Laboratory, Bushland
[2]West Texas A&M University, Canyon
[3]Texas AgriLife Research, Amarillo
Email: richard.todd@ars.usda.gov.

ABSTRACT

Diversion of corn grain to ethanol production more than doubled from 2003 to 2008. A feed byproduct of ethanol fermentation is distillers' grains (**DG**). Optimum beef cattle diets have crude protein (**CP**) contents of 12.5 - 13.5 %, but diets that contain DG in place of corn can have CP that varies from 15 % to more than 20 %. Most excess N in cattle diets is excreted, so that feeding DG has the potential to increase N lost from manure as ammonia. Twenty-five months of near-continuous ammonia emission data at 2 feedyards (Feedyards A and E) were used to assess the effect of feeding wet DG (**WDG**) on ammonia emissions. Three distinct feeding periods were identified: 1) corn-based rations were fed at the 2 feedyards from Feb07 through Dec07 (**Pre-WDG**); 2) up to 24 % WDG was substituted for corn in rations at Feedyard A (**FYA**) from Feb08 through Oct08, while Feedyard E (**FYE**) continued feeding a corn-based ration (**FYA-WDG**); 3) corn-based rations were fed at both feedyards from Dec08 through Feb09 (**Post-WDG**). During the Pre-WDG period, CP in rations was not significantly different ($P=0.08$) between the feedyards (14.4 % at FYA and 13.5 % at FYE). Ammonia emission, also, was not significantly different ($P=0.79$, 98 and 95 g NH_3-N $head^{-1}\ d^{-1}$ at FYA and FYE, respectively). During the FYA-WDG period, both CP ($P=0.0006$) and per capita ammonia emission rate ($P=0.003$) were significantly greater at FYA (16.3 % CP, 149 g NH_3-N $head^{-1}\ d^{-1}$) than at FYE (12.2 % CP, 82 g NH_3-N $head^{-1}\ d^{-1}$). Crude protein was not significantly different ($P=0.20$) during the Post-WDG period, though ammonia emission was greater ($P=0.01$) at FYA, compared with FYE. Feeding WDG utilizes a valuable byproduct increasingly available as corn is diverted to ethanol production, but the increased CP due to WDG results in increased ammonia emissions. The feeding of WDG thus complicates efforts to reduce ammonia emissions from cattle feedyards.

INTRODUCTION

Finishing diets for beef cattle in the southern Great Plains typically contain 12.5 to 13.5% crude protein (**CP**), with 13.5% being the most frequent value used by consulting nutritionists (Vasconcelos and Galyean, 2007). Nitrogen in diets in excess of the physiological needs of animals is excreted, with most N in the urine as urea. Excreted urea is readily hydrolyzed and converted to ammonium, which makes it available for volatilization and loss to the atmosphere as ammonia gas. Ammonia emission from cattle manure increased with increased dietary CP (Cole et al., 2006; Todd et al., 2006), though the shape of the response is uncertain. An effective way to minimize ammonia loss is to maintain CP at optimum levels to prevent excess excreted N.

United States ethanol production has grown greatly during the past 5 yr, increasing 321 % from 2800 mil gal in 2003 to 9000 mil gal in 2008 (EIA, 2009; RFA, 2009). During the same period, corn used for ethanol production increased 308 %, from 1168 mil bu to 3600 mil bu. Currently, about 97 % of feedstocks used for ethanol production is corn grain, with 23 % of the 2008 crop used to produce ethanol (RFA, 2009).

After ethanol production, about a third of the corn remains as a feed byproduct called distillers' grains (**DG**). Distillers' grains are dewatered centrifugally, resulting in wet DG (**WDG**), or, alternatively, mechanically dried to produce dry DG (**DDG**). Either byproduct contains from 30 to 35 % CP (NRC, 2000). Cattle diets that contain DG can have CP contents that vary from 15 % to more than 20 %, depending on the mix of DG and other CP sources. Rations with this much CP exceed the physiological requirements of beef cattle, so that feeding DG has the potential to increase the nitrogen lost from manure as ammonia.

We began multi-year, continuous monitoring of ammonia emissions at 2 feedyards located in the Texas Panhandle in late 2006. In January 2008, 1 of the feedyards began feeding WDG in cattle rations. This offered us the opportunity to compare resulting ammonia emissions from the 2 feedyards and determine the effect of WDG on ammonia emissions. Our objective was to compare ammonia emissions between the 2 feedyards during 3 time periods: before, during and after feeding WDG at 1 of the feedyards.

MATERIALS AND METHODS

Feedyard Characteristics and Feeding Regimes

Research was conducted at 2 beef cattle feedyards located in the Texas Panhandle, Feedyard A (**FYA**) and Feedyard E (**FYE**), during a 25-mo period from Feb07 to Feb09. Total cattle pen areas were 36.4 and 34.1 ha for FYA and FYE, respectively. Feedyard A averaged 12,684 head of cattle; but cattle population was highly variable, (maximum = 15,430, minimum = 8,927) mean occupancy was 56 ± 7 % (mean ± SD). Head count at FYE averaged 19,620 (maximum = 22,437, minimum =1 7,260) and mean occupancy was 78 ± 6 %.

The commercial feedyards cooperatively provided monthly data, including head counts, mean cattle weight, total feed fed, average daily gain, days on feed, and diet composition; though the information provided differed for each feedyard (see Cole and Todd, this proceedings, for additional details on rations). We collected feed samples either bi-monthly or monthly by sampling rations from the feed bunks of 5 pens. Samples were dried to determine dry matter content, wet-digested and then analyzed for total N using a flow injection analyzer (Lachet Instruments, Milwaukee, WI[1]) and CP content calculated.

Three distinct feeding regimes were identified and named, based on the diet fed at FYA. The first ran from Feb07 through Dec07, when the 2 feedyards fed similar rations based on steam flaked corn (**SFC**); we called this the **pre-WDG** ration period. The second commenced from Feb08 and

[1] Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

extended through Oct08. During this period, FYA substituted some of the SFC in diets with WDG, while FYE continued feeding SFC; this was called the **FYA-WDG** ration period. During Nov08 FYA eliminated all WDG from rations and both feedyards fed SFC-based rations from Dec08 to Feb09; we called this the **Post-WDG** ration period.

Ammonia Emissions

Ammonia emissions at the 2 feedyards were quantified using an atmospheric inverse dispersion model (Windtrax, Thunderbeach Scientific, Nanaimo, BC, Canada). Optimally, the dispersion model uses as inputs wind speed, wind direction, friction velocity, turbulence statistics, and Monin-Obukhov length (Flesch and Wilson, 2005). These input variables were provided using measurements from a 3-dimensional sonic anemometer (Model 81000, R.M. Young, Traverse City, MI) that was deployed on a 7.2 m tower located near the center of each feedyard. Sonic anemometer data were collected at 10 Hz frequency by a datalogger (CR23X, Campbell Scientific, Logan, UT). Means, variances, and covariances were calculated every 15-min, coordinate rotations were employed, and wind speed, wind direction, friction velocity (**u***), standard deviations of wind velocity components and Monin-Obukhov length (**L**) were calculated (van Boxel et al., 2004).

The inverse dispersion model also requires a measurement of atmospheric ammonia concentration. At each feedyard, an open path laser (Boreal Laser, Inc., Spruce Grove, AB, Canada) specifically tuned to detect ammonia was deployed. At FYA, the laser was mounted on a tower at 3.5 m and integrated ammonia concentration along a 335-m path over the feedyard pens. At FYE, the laser was mounted at 4.2 m and operated over a 350-m path over the feedyard pens. Lasers measured concentration every 50 s and 15-min means were calculated. Background atmospheric ammonia concentration was assumed to be constant at 10 $\mu g\ m^{-3}$ (Todd et al., 2006).

Model runs were executed on monthly input data sets using ensembles of 10,000 particles. Roughness length was set at 0.09 m (Todd et al., 2008). Input data were excluded when $u^* < 0.15\ m\ s^{-1}$ (low wind speed) or $|L| < 10$ (extreme atmospheric stability or instability). For each month, ammonia emission rates (kg d^{-1}) for each 15-min were averaged and the mean daily emission rate for the month taken as the average of the 96 15-min composite emission rates. Per capita emission rate (g NH_3-N $head^{-1}\ d^{-1}$) was calculated by dividing the mean monthly emission rate by the monthly head count provided by the feedyard.

The changing diets at FYA and the relatively constant diets at FYE allowed us to analyze the effect of feeding WDG on ammonia emissions. Using t-tests that assumed unequal variances, we compared differences in CP, ammonia emissions, and ammonia-N loss as a fraction of fed N between the feedyards during each ration period; Pre-WDG (Feb07-Dec07), FYA-WDG (Feb08-Oct08), and Post-WDG (Dec08-Feb09). The month at the beginning of a ration change was considered a transition period and was not included in analysis. Significance was assigned to differences at the $P < 0.05$ level.

RESULTS

Crude Protein

Steam flaked corn comprised 65 ± 1.0 % of the rations fed at FYA from Feb07 to Dec07. Wet distiller's grains were phased into FYA rations beginning Jan08, which reduced corn and increased WDG until SFC comprised 41 % of rations in Oct08. Crude protein at FYA on 3Feb08 was 12.9 %, and increased to a maximum of 19.1 % on 31Aug08, as WDG was added to rations

Table 1. Crude protein (CP) in rations, per capita NH_3-N emission rate, and NH_3-N loss as fraction of N fed at 2 feedyards compared. Rations based on steam-flaked corn (SFC) were fed at both feedyards during Pre-WDG. During FYA-WDG, Feedyard A substituted wet distillers' grains for up to 37 % of SFC; Feedyard E (FYE) continued to feed SFC, but reduced CP. During Post-WDG, both feedyards fed SFC-based rations

	Feedyard A	Feedyard E	SED[2]	P > t	n
Ration crude protein	--------------%--------------				
Pre-WDG[1]	14.4	13.5	0.14	0.08	6
FYA-WDG	16.3	12.2	0.62	0.0006	9
Post-WDG	12.8	11.4	0.50	0.20	3
Per capita NH_3-N emission rate	---------g $head^{-1}$ d^{-1}---------				
Pre-WDG	98	95	7.2	0.79	11
FYA-WDG	149	82	12.9	0.003	9
Post-WDG	85	45	2.8	0.01	3
NH_3-N loss as fraction of N fed	--------------%--------------				
Pre-WDG	52	53	0.04	0.79	11
FYA-WDG	69	51	0.06	0.02	9
Post-WDG	58	30	0.05	0.02	3

[1]WDG = wet distillers grain
[2] Standard error of the difference.

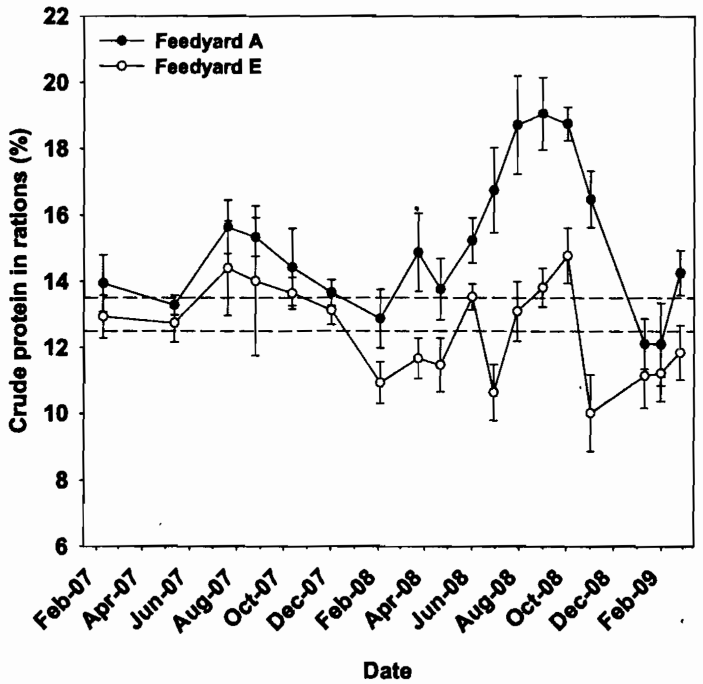

Figure 1. Crude protein (dry matter basis) in rations. Horizontal dashed lines indicate the optimum range of crude protein in cattle diets (12.5 - 13.5 %). The error bars represent the standard deviation of a mean, with n=5.

(Figure 1). Wet distillers grains were removed from rations during Nov08, so that CP by early December decreased to 12.1 %. During the same period, CP at FYE was less when compared with the previous year, reaching a low of 10.6 % on 29Jun08 (Figure 1). Analysis for N content in corn used at each feedyard showed a seasonal trend in corn CP that partly accounted for the similar tracking of the ration CP for the 2 feedyards observed in Figure 1.

Crude protein contents of the corn-based rations fed at the 2 feedyards were not significantly different (P = 0.08) during the pre-WDG ration period (Table 1). However, rations at FYA did tend to have more CP than rations at FYE (Figure 1). Mean CP at FYA (16.3 %) was significantly greater (P=0.0006) than that at FYE (12.2 %) during the FYA-WDG ration period (Table 1). During the Post-WDG period, there was no difference (P = 0.20) in CP between the 2 feedyards (Table 1).

Ammonia Emissions

Ammonia emissions at both feedyards followed an annual pattern of lowest emissions in the winter and highest emissions in the summer, with spring and autumn intermediate (Figure 2). During the Pre-WDG ration period, monthly emissions at the 2 feedyards were mostly similar. Beginning in Mar08 during the FYA-WDG ration period, ammonia emissions of the 2 feedyards diverged, with FYA per capita emission rate ranging from 44 % (Mar08) to as much as 144 % (Oct08) greater than that at FYE. Ammonia emissions decreased greatly during the Post-WDG period, because of cooler winter temperatures; and, at FYA, because of greatly reduced CP. However, even though there was no significant difference in CP during the Post-WDG period, ammonia emissions at FYA remained greater than those at FYE.

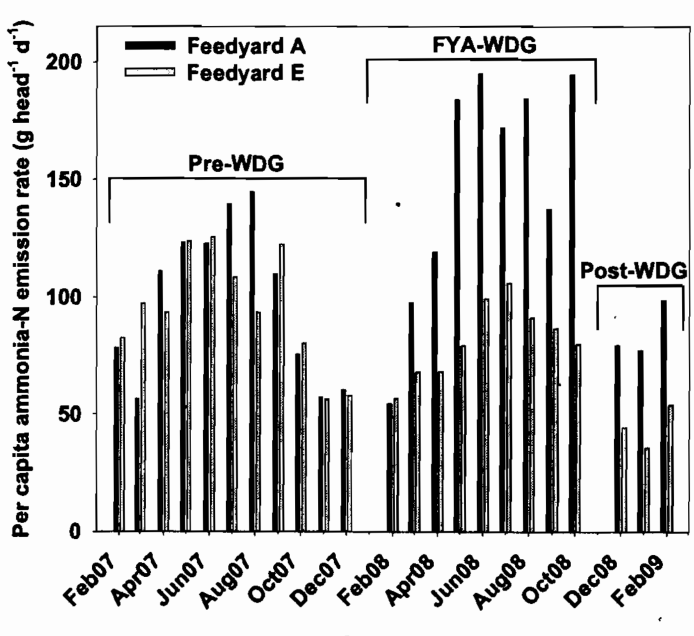

Figure 2. Monthly mean per capita ammonia-N emission rate. Rations during Pre-WDG were based on steam-flaked corn at both feedyards. Rations during FYA-WDG at Feedyard A included wet distillers grains, while Feedyard E rations were based on steam-flaked corn. Rations during Post-WDG were based on steam flaked corn at both feedyards.

There was no difference (P = 0.79) in ammonia emissions between the 2 feedyards during the Pre-WDG period, when per capita emission rates at FYA and FYE averaged 98 and 95 g $head^{-1}$ d^{-1}, respectively (Table 1). However, during FYA-WDG, per capita ammonia emission rate at FYA (149 g $head^{-1}$ d^{-1}) was significantly greater (P = 0.003) than at FYE (82 g $head^{-1}$ d^{-1}). During the Post-WDG period, ammonia emission rate at FYA was 89 % greater (P=0.01) than that at FYE.

Ammonia-N lost as a fraction of fed N followed a pattern similar to per capita ammonia emissions, with no significant difference observed during the Pre-WDG period, followed by a significantly larger fraction of loss at FYA during the FYA-WDG and Post-WDG periods (Table 1). At FYA during the FYA-WDG period, 5 out of 9 mo had ammonia-N losses that exceeded 75 % of fed N; loss in May08 was almost 90 % of fed N (Figure 3). This magnitude of ammonia-N loss indicates that either ammonia emissions were overestimated, fed N was underestimated, or both. Cattle population in May08 at FYA declined by 25 % from the previous month to its lowest population of 8927 head, about 40 % occupancy. So many empty pens could have impacted the accuracy of the inverse dispersion model, which requires that the source area be accurately mapped and assumes that source strength is homogenous across the source area.

DISCUSSION

Ammonia emissions from cattle manure are sensitive to CP in diets. High per capita emissions (262 g NH_3-N $head^{-1}$ d^{-1}, 72 % of fed N) at a Canadian feedyard were attributed to high CP rations (20 %) due to

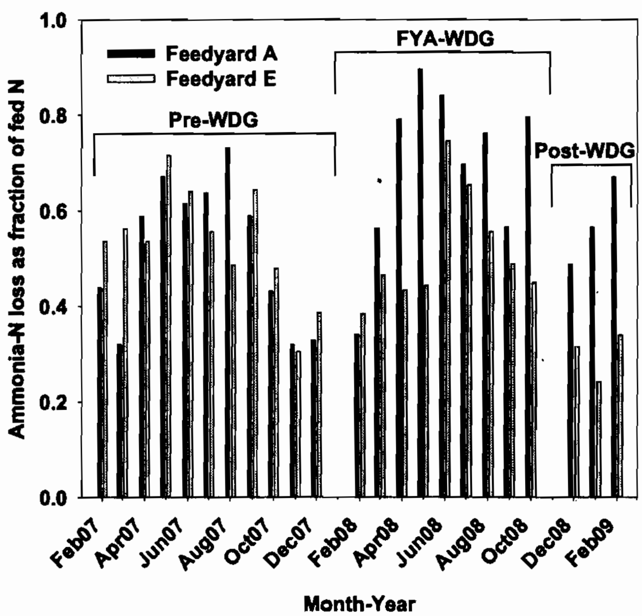

Figure 3. Monthly mean ammonia-N loss as a fraction of fed N. Rations during Pre-WDG were based on steam-flaked corn at both feedyards. Rations during FYA-WDG at Feedyard A included wet distillers grains, while Feedyard E rations were based on steam-flaked corn. Rations during Post-WDG were based on steam flaked corn at both feedyards.

DG (van Haarlem et al., 2008). Corn gluten feed added to feed increased CP from 13.5 % to 15 % at a commercial feedyard, which resulted in a 10 % increase in summer ammonia emissions and a 64 % increase in winter ammonia emissions (Todd et al., 2008). Cole et al. (2006) found that *in vitro* N volatilization from manure increased by 29 % when CP fed to steers increased from 11.5 to 13 %. Todd et al. (2006) applied manure from steers fed either 11.5 or 13 % CP to constructed feedyard surfaces and found that ammonia emissions increased 39 % at 13 % CP compared with the 11.5 % CP diet.

In this study, ammonia emissions increased 82 % and NH_3-N loss as a fraction of fed N increased 35 % at FYA when WDG was fed, compared with FYE. This difference in emissions was because CP at FYA, which ranged from 13 to 19 % and averaged 16.3 %, was in excess of animal needs; while CP at FYE was at or below the recommended optimum. However, very high ammonia-N loss as a fraction of fed N during some months with low occupancy at FYA suggested that the inverse dispersion model may have overestimated emissions when occupancy was around 50 % or less.

The persistence of greater ammonia emissions at FYA during the Post-WDG period was unexpected. Manure N content tended to be greater at FYA (data not shown), but this alone wouldn't account for the difference. Temperature and wind speed were similar at both feedyards, though further fine-scale analysis of environmental data, including precipitation and pen surface wetness, is needed. Additional analysis of the interplay of source area and occupancy is needed to assess its effect on performance of the inverse dispersion model.

CONCLUSIONS

Feeding WDG at CP levels that exceeded the physiological optimum for beef cattle resulted in increased ammonia emissions. This poses a feed management problem for cattle producers who seek to reduce ammonia emissions, yet face a feed supply environment increasingly dominated by the growing demand for corn-based ethanol. The feeding of DG thus complicates efforts to reduce ammonia emissions from cattle feedyards.

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LITERATURE CITED

Cole, N.A., P.J. Defoor, M.L. Galyean, G.C. Duff, and J.F. Gleghorn. 2006. Effects of phase-feeding of crude protein on performance, carcass characteristics, serum urea nitrogen concentrations, and manure nitrogen of finishing beef steers. J. Anim. Sci. 84:3421-3432.

EIA. 2009. Energy Information Agency. http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table1_6.pdf. Accessed July 31, 2009.

Flesch, T.K., and J.D. Wilson. 2005. Estimating tracer emissions with a backward Lagrangian stochastic technique. Pages 513-531 In Micrometeorology in Agricultural Systems. Agronomy #47. M.K. Viney, ed. ASA, CSA, SSSA, Madison, WI.

NRC. 2000. Nutrient Requirements of Beef Cattle. 7th Rev. Ed. National Academy Press, Washington, DC.

RFA. 2009. Renewable Fuels Association. http://www.ethanolrfa.org/industry/statistics/. Accessed July 31, 2009.

Todd, R.W., N.A. Cole, and R.N. Clark. 2006. Reducing crude protein in beef cattle diet reduces ammonia emissions from artificial feedyard surfaces. J. Environ. Qual. 35:404-411.

Todd, R.W., N.A. Cole, R.N. Clark, T.K. Flesch, L.A. Harper, and B.-H. Baek. 2008. Ammonia emissions from a beef cattle feedyard on the southern High Plains. Atmos. Environ. 42:6797-6805

van Boxel, J.H., G. Sterk, and S.M. Arens. 2004. Sonic anemometers in aeolian sediment transport research. Geomorphology 59:131-147.

van Haarlem, R.P., R.L. Desjardins, Z. Gao, T.K. Flesch, and X. Li. 2008. Methane and ammonia emissions from a beef cattle feedlot in western Canada for a twelve-day period in the fall. Can. J. Anim. Sci. 88:641-649.

Vasconcelos, J.T.,and M.L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech Universtiy survey. J. Anim. Sci. 85:2772-2781.

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