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Effects of Corn Processing Method and Dietary Inclusion of Wet Distiller's Grain with Solubles on Energy Metabolism and Enteric Methane Emissions of Finishing Cattle

Few studies have used steam-flaked corn (**SFC**)-based diets to evaluate the effects of wet distiller's grains with solubles (**WDGS**) in finishing cattle diets. The effects of corn processing method and WDGS on energy metabolism, C and N balance, and enteric methane (**CH_4**) production were evaluated in four Jersey steers using open-circuit, indirect respiration calorimetry. A 2 x 2 factorial arrangement of treatments was used in a Latin square design. The factors consisted of corn processing method (SFC or dry-rolled corn [**DRC**]) and inclusion of corn-based WDGS (0 or 30% on a DM basis). The diets were balanced for degradable intake protein (**DIP**) and fat and cattle were fed at 2x maintenance energy requirements. Each Latin square period consisted of 14 d diet adaptation and 7 d of fecal, urine, and gas (oxygen consumption, carbon dioxide and CH_4 production) collections. As a proportion of gross energy (**GE**) intake, grain processing method did not affect ($P \geq 0.11$) fecal, digestible, urinary, and metabolizable energy, or heat production. In contrast, retained energy tended to be greater ($P = 0.09$) for cattle consuming SFC- than DRC-based diets. Feeding 30% WDGS did not affect ($P \geq 0.17$) fecal, digestible, urinary, metabolizable, and retained energy, or heat production as a proportion of GE intake. Steers consuming SFC-based diets produced less ($P = 0.05$) CH_4 than steers consuming DRC diets (L/day; L/kg of DM intake, and % of GE intake). When diets were balanced for fat content, feeding 30% WDGS did not affect enteric CH_4 production. Total C excretion ($P < 0.01$) was greater for cattle consuming DRC- than SFC-based diets; thus, cattle consuming SFC-based diets retained more C. Inclusion of WDGS did not affect ($P \geq 0.21$) C balance. Grain processing method did not affect N balance ($P \geq 0.13$), although apparent N digestibility was greater ($P = 0.02$) for cattle consuming DRC- than SFC-based diets. Cattle consuming diets containing 30% WDGS tended to excrete more ($P = 0.09$) total N and excreted more ($P = 0.02$) N in the urine than cattle fed diets containing no WDGS. We attribute this in part to greater N intake. Apparent N digestibility (g/d and % of N intake; $P < 0.03$) and N retained ($P < 0.01$) were also greater in cattle consuming diets containing 30% WDGS. Results suggest that when fed at similar energy intakes, cattle consuming SFC-based diets produce less enteric CH_4 and retain more energy than cattle fed DRC-based diets; however, inclusion of WDGS at 30% of diet DM had little effect on CH_4 production and energy metabolism. Finishing cattle fed a DRC-based diet excrete a greater amount of C than cattle fed a SFC-based diet. Inclusion of WDGS at 30% of diet DM increased urinary N excretion.

Nutrient Concentrations and Proportions in Particle Size Fractions of Corn Steam Flaked to Different Bulk Densities

Previous studies have suggested the chemical composition of grains may change during the steam flaking process. The particle size distribution that occurs during steam flaking could be responsible for the differences in the chemical composition noted between steam-flaked corn and unprocessed grain. Corn was steam-flaked to bulk densities of 283, 335, and 386 g/L (22, 26, and 30 lb/bu, respectively) and was dry-sieved to determine the proportions of the original corn in particle size fractions ranging from < 600 to >8,000 µm. Total starch, CP, NDF, P, ether extract (EE), and ash concentrations were determined in the individual fractions. Concentrations of CP, NDF, P, EE, and ash of the intact flakes were generally not affected ($P \geq 0.09$) by flake bulk density. The greatest proportion of particles in grab samples (DM basis) was in the >8,000-µm fraction, with the smallest proportion associated with the 600-µm sieve fraction. The proportions of NDF, P, EE, and ash present in particles >8,000 µm decreased ($P < 0.05$) as flake bulk density decreased. In addition, the proportions of total starch within particle sizes of 4,760 to 8,000 µm and 1,180 to 2,360 µm were greater ($P \leq 0.02$) for 283 g/L flakes than for 335 and 386 g/L flakes. Within the range of bulk densities evaluated, certain nutrients such as P and fat were more concentrated in the finer particles created during the steam flaking process. If smaller particles are disproportionately under- or over-sampled, flaked corn will appear to differ chemically from the original grain being flaked.

Ammonia Concentrations and Flux at Feedyards: A Summary of Research Results (see Hristov et al., 2011 for references)

Table 1. Summary of ammonia concentrations (µg/m^3) at feedlots

Reference	Months/season	Location	Mean or Range
Hutchinson et al. (1982)	April-July	Colorado	290 to 1,200
McGinn et al. (2003)	May	Canada	66 to 503
	July		155 to 1,488
Todd et al. (2005)	Summer	Texas	90 to 890
	Winter		10 to 250
Baek et al. (2006)	Summer	Texas	908
	Winter		107
McGinn et al. (2007)	Jun.-Oct.	Canada	46 to1,730
Rhoades et al. (2008)	March	Texas	305
	August		540
Cole et al. (2011)	Summer	Texas	360
	Winter		605

Table 2. Summary of ammonia emissions from commercial beef cattle feedlots using N mass balance or micrometeorology techniques

Reference	Season	Ammonia flux rate (g m^{-2} h^{-1})	Ammonia emission factor (g $head^{-1}$ d^{-1})	% of N fed
Hutchinson et al. (1982)	April–July	0.061 - 0.241	50	-
James et al. (1997)	Summer	-	-	50 to 70
Bierman et al. (1999)	Summer	-	-	53 to 63
Erickson et al. (2000)	Winter/Spring	-	-	31
Erickson et al. (2000)	Summer	-	-	54
Wood et al. (2001)	--	0.013 - 0.168	-	-
Harper et al. (2004)	Summer	-	-	53
Harper et al. (2004)	Winter	-	-	29
Todd et al. (2005)	Summer	0.252	-	55
Todd et al. (2005)	Winter	0.121	-	27
Todd et al. (2005)	Annual	0.130	-	41
Cole et al. (2006)	Winter/Spring	-	66 to 108	51 to 65
Baek et al. (2006)	Summer	0.220	-	-
Baek et al. (2006)	Winter	0.019	-	-
McGinn et al. (2007)	June–October	0.302	140	63
Flesch et al. (2007)	Summer	-	150	64
Rhoades et al. (2008)	March	0.208	-	34
Rhoades et al. (2008)	August	0.258	-	42
Todd et al. (2008)	Summer	-	126	68
Todd et al. (2008)	Winter	-	68	36
Todd et al. (2008)	Annual	-	97	53
van Haarlem et al. (2008)	Fall	-	262[1]	72[1]
Staebler et al. (2009)	September	0.230 to 0.317	204 to 283	-
Todd et al. (2009)	Annual	-	82 to 149	51 to 69
Cole and Todd (2011)	Summer	0.230	123	52
Cole and Todd (2011)	Winter	0.130	65	27
Summer Mean		0.252	138.7	56.7
Winter Mean		0.090	68.0	30.2
Annualized Mean		0.174	119.4	47.6

[1] 20% crude protein diet

Nitrogen and Phosphorus Balance of Beef Cattle Feedyards

Large quantities of nutrients enter beef cattle feedyards in feed ingredients. These nutrients subsequently "leave" the yard in finished cattle, manure, or through the atmosphere. A better understanding of the movement of these nutrients would be helpful in developing nutrient management plans and technologies to capture more of these nutrients in usable form. To that end, diet, fresh feces, and air dried manure samples were collected monthly at two commercial feedyards in the Texas Panhandle over a year. The feedyards provided data on cattle head counts, body weights, and feed consumption. Nitrogen (N) and phosphorus (P) retention were calculated using NRC (2000) equations. Diet digestibility was calculated using acid insoluble ash as an indigestible marker. Urinary N and P excretion were determined by difference and N volatilization losses were estimated via the change in the N:P ratio between the diet and air-dried manure, and as N unaccounted for in the total N balance. Daily N intake averaged 162 g/head (362 lb/ 1,000 head) and daily N retention averaged 23 g/head (51 lb/1,000 head). Approximately 141 kg (311 lb) of N was excreted daily per 1,000 head: 36 % in feces and 64 % in urine. Approximately 67 kg (147 lb; 41 % of N intake) was subsequently captured in manure. Of the N intake, 25% in winter to 58 % in summer (mean 44.3 %) was apparently lost via volatilization. When metabolizable protein (MP) intake exceeded animal requirements, N volatilization losses increased linearly ($r^2 = 0.53$: $P < 0.001$)(Tables 3 & 4). Daily P intake averaged 29 g/head (64 lb/1,000 head). Approximately 23 kg (51 lb) of P was excreted daily per 1,000 head; 63 % in feces and 37 % in urine. Nitrogen excretion and volatilization losses were affected by diet and season.

Table 3. Effects of metabolizable protein-N (MPN) intake status on N metabolism averaged over two feedyards for one year.[1]

Item	Deficient	Adequate	High	Excessive
(MP-N intake) – (MP-N required)	-10.70	8.87	19.26	27.65
Ration N, %	1.83	2.13	2.36	2.41
Ration P, %	0.36	0.36	0.33	0.52
Manure N, %	2.95	2.95	2.92	2.65
Manure P, %	0.74	0.85	0.78	0.98
DMI, kg	7.72	7.90	7.88	8.01
N intake, g/d	140.2	168.6	178.3	191.3
N digestion, %	64.5	70.3	68.0	75.3
Fecal N, g/d	48.7	49.2	57.4	47.7
Urine N, g/d	67.3	93.9	96.2	119.0
N volatilization, % of N intake	21.0	41.2	45.0	53.9
N volatilization, g/head daily	29.8	69.5	79.9	103.1
Manure N, % of N intake	56.0	40.9	39.8	33.9

[1] MPNstatus = (Daily metabolizable protein-nitrogen intake) – (Daily metabolizable protein-nitrogen required).

Table 4. Regression of MPN status vs. N volatilization losses from two feedyards [1]

Dependent variable & data set	Equation	R^2	RMSE	$P <$
N loss, g/head				
All data	47.7 + 1.444 (MPNstatus)	0.59	17.85	0.001
Negative MPNstatus	29.30 – 0.343 (MPNstatus)	0.03	12.50	0.500
Positive MPNstatus	40.14 + 1.852(MPNstatus)	0.53	17.70	0.001
N loss, % of N intake				
All data	30.24 + 0.602 (MPNstatus)	0.43	10.17	0.001
Negative MPNstatus	17.57 – 0.535 (MPNstatus)	0.12	8.47	0.131
Positive MPNstatus	26.62 + 0.801(MPNstatus)	0.41	9.89	0.001

[1] MPNstatus = (Daily metabolizable protein-nitrogen intake) – (Daily metabolizable protein-nitrogen required). RMSE = Root mean square error.

Effects of Fat, a Urease Inhibitor, Zeolite, and Distiller's Grains on Ammonia Emissions from Beef Cattle Feedyards

Ammonia emissions from beef cattle feedyards may comprise 40% or more of N 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, a urease inhibitor (NBPT), and zeolite on potential ammonia emissions from a feedlot surface. In Trial 1, fat (as corn oil), alum, NBPT, or potassium zeolite (clinoptilotile) were added to lab-scale flow through chambers that contained simulated feedlot surfaces. Ammonia losses were captured using acid traps. In Trial 2, five beef steers were fed one of five high-concentrate 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 design. Each period of the Latin square was 21 days in length. During the last five days of each period, total feces and urine output were collected to determine nutrient digestion and retention. Feces and urine collected from each steer (1% of daily output) were then used in the lab-scale flow through chambers to estimate potential ammonia losses. In Trial 1, zeolite, NBPT, alum, and fat additions to an artificial feedyard surface decreased ammonia losses by 51 to 86%; the effects of the NBPT and zeolite appeared to be synergistic (Table 5). In the Trial 2, apparent protein digestion, N retention, and N excretion were not affected by dietary fat or zeolite. In vitro ammonia losses from excreted feces and urine 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 (Table 6). These results suggest that fat and zeolite additions to feedlot pen surfaces can potentially decrease ammonia emissions from beef cattle feedyards.

Crude protein concentrations of finishing diets are normally increased to levels well above animal requirements whenever distiller's grains (DGS) are included in finishing diets at concentrations above 15% of dietary DM. Most of this excess N will be excreted in urine and be a potential source of ammonia emissions. We measured ammonia emission from two Texas feedyards almost continuously for 25 months. Two distinct feeding periods were recognized: (1) similar steam-flaked corn-based diets were fed at both yards (**PRE-DG**), and (2) inclusion of DGS (up to 25%) at Yard A but not at Yard E (**FYA-DG**). During the Pre-DG period, dietary

CP averaged 13.5 to 14.4% at both yards and ammonia emissions per head at both yards were similar. During the FYA-DG period, dietary CP averaged 16.3% at Yard A and 12.2% of DM at Yard E and ammonia emissions per head were 45% greater at Yard A than Yard E (149 vs. 82 g/head daily). Feeding DGS utilizes a valuable byproduct; however, it also complicates efforts to reduce ammonia emissions from feedyards.

Table 5. 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/day [a]	NH_3-N, % decrease [a]	Final pH
Control (no additive	6.49	--	7.53
Alum, 36 g	1.60	75.3	5.66*
Zeolite, 18 g	3.19	49.0	8.02
Zeolite, 36 g	2.14	67.1	8.14
Corn oil, 36 g	0.77	88.1	6.83*
NBPT	2.74	57.9	8.05
NBPT + zeolite	1.53	76.4	8.04
SEM	0.27	4.19	0.14

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

Table 6. 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 seven days.

Item	0% fat	3% fat	6% fat	1% zeolite	2% zeolite	SEM
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]	13.41
Ending soil NH_x-N, mg	597 [d]	296 [c]	279 [c]	254 [c]	235 [c]	29.9
NH_3-N + NH_x-N, % of added N	95.5 [d]	50.1 [c]	47.5 [c]	38.7 [c]	42.6 [c]	14.02

[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 ($P < 0.05$).

Nitrogen Distribution in Pen Surface of Beef Cattle Feedyards and Effects of Urine Application

Beef cattle feedlots can emit significant quantities of ammonia that may adversely affect air quality and decrease the fertilizer value of manure. The major source of ammonia loss may be urinary urea. We conducted three studies to evaluate the effects of urine on the chemistry of feedlot pen surfaces. In Exp.1, samples were collected from the loose surface manure and the underlying layers (dry hard pack, wet hard pack, soil) of nine pens at each of three commercial feedyards. Samples were collected from an area that had recent (less than 10 minutes) urine deposition, and an area devoid of urine. The samples were analyzed for DM, ash, pH, electrical conductivity (EC), nitrate-N, ammonium-N, and total N, C, and P. The loose surface manure from urine spots had lower ($P < 0.05$) DM content (59.7 vs. 88.2%), higher ($P < 0.05$) pH (8.08 vs. 7.80), and greater ($P < 0.05$) EC (1.45 vs. 1.22 S/m), ammonium-N (6,755 vs. 2,381 ppm), total N (3.00 vs. 2.73%), and ammonium-N:total N (21.8 vs. 8.5%) than urine-free areas. In Exp. 2 (Summer) and 3 (Spring), 4 L of deionized water or artificial urine (21.4 g of urea/L) were applied to 1 m square plots (6/treatment) on a feedlot surface. The loose manure on the pen surface was sampled for 7 d and chemically analyzed. Compared to untreated plots, ammonium-N concentrations of plots treated with artificial urine increased ($P < 0.001$) from 391 to 6,343 ppm and the pH increased from 8.1 to 8.5 in less than 5 min following application and remained elevated ($P < 0.05$) for 79 to 96 h. Water applications caused a short term (2 to 4 h) increase in ammonium-N concentrations. These results support the hypothesis that ammonia losses from feedlot pens occur rapidly from urine spots. Therefore, (1) methods that do not take this into account will greatly underestimate ammonia emissions, and (2) for optimal effectiveness, pen surface amendments to control ammonia losses must continuously be on the pen surface.

Challenges in Using Flux Chambers to Measure Ammonia Emissions from Feedlot Pen Surfaces and Retention Ponds

Several methodologies are available to estimate ammonia emissions from livestock operations, but few have been adequately validated for accuracy. Dynamic, flow-through flux chambers are frequently used; however, ammonia emissions from the surfaces are affected by atmospheric turbulence, atmospheric ammonia concentration, source strength, temperature, moisture, and media pH; several of which can be affected by the chamber. Studies have shown that ammonia emissions estimated using flow-through chambers are affected by air exchange rate; however, these chamber fluxes have not been directly compared to the flux from the same source when unaffected by a chamber. In two studies, we compared measured ammonia losses from an "unaffected" source to the same source when the air exchange rate ranged from 0 to 4 turnovers per minute. To simulate a feedlot retention pond, buffered ammonium sulfate solutions with pH values of 7.6, 8.6, or 9.6 were used as a surrogate ammonia source. To simulate a feedlot surface, similar buffer solutions were added to a cellulose media. With both simulated retention pond and pen surfaces, ammonia losses increased with increased air flow. Losses at 4 turnovers per minute were approximately 50% of losses from open-unaffected containers. Losses at 0.5 turnovers per minute were 25% or less of losses from the unaffected sources. Based on fitted exponential equations, air turnover rates of 8.9 to 18.8 (mean = 14.9 turnovers/minute) were required to obtain N flux rates equal to 95% of the flux from the open chambers. At low flow rates, source strength differences were sometimes not accurately determined. Previous studies have noted a large spatial variability in ammonia flux from pen surfaces with coefficients of variation ranging from 23 to 192%. Because of this large spatial variability, the number of ammonia flux estimates required to be 95% confident that the estimated mean is within 20% of the true mean (determined as $CV^2/100$) ranges from 5 to 369; with a mean of approximately 75. These findings indicate that flux chambers will not provide accurate estimates of ammonia flux from pen or lagoon surfaces and that large numbers of samples may be required when using chambers for treatment comparisons. Ammonia emission factors determined using flux chambers must be viewed with extreme caution.

Methane Emissions from a New Mexico Dairy Lagoon System

Methane is a greenhouse gas with a global warming potential twenty-five times that of carbon dioxide. Animal agriculture is recognized as a significant source of methane to the atmosphere. Dairies on the Southern High Plains of New Mexico and Texas are typically open lot, and the major sources of methane from these dairies are probably the enteric emissions from cattle and emissions from wastewater lagoons. Our objective was to quantify methane emissions from the wastewater lagoons of a commercial dairy located in eastern New Mexico. Research was conducted during seven days in August, 2009, at a 3,500-cow open lot dairy with flush alleys. Methane concentration over three interconnected lagoons (total area 1.8 ha or 4.5 ac) was measured using open path lasers. Background methane concentration was measured using gas chromatography. Wind and turbulence data were measured using a three-axis sonic anemometer. Emissions were estimated using an inverse dispersion model. Background methane concentrations averaged 1.83 ppm and concentrations over the lagoons ranged from 3 to 12 ppm, with an average of 5.6 ppm. Methane flux density ranged from 165 to 1,184 $\mu g\ m^{-2}\ s^{-1}$ with a mean daily methane flux density of 404 kg/ha (360 lb/ac). The per capita daily methane emission rate averaged 0.21 kg/head (0.46 lb/head). These results indicate that uncovered anaerobic lagoons can be a significant source of methane emitted from Southern High Plains dairies; thus, lagoons could be a significant control point for reducing emissions.

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