Effects of Forage Quality, MDGS, and Monensin on Performance, Methane Concentration, and Ruminal Fermentation of Growing Cattle

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Summary

A growing study was conducted to evaluate a novel method for measuring methane concentration by feedlot cattle, and to determine the effects of forage quality, inclusion of modified distillers grains plus solubles (MDGS), and presence or absence of monensin on performance, methane concentration, and rumen fermentation characteristics. Performance was improved by use of high-quality forage and MDGS, while response to monensin was variable across basal diet type. Response of methane concentration and volatile fatty acid (VFA) profile due to diet was variable and subject to multiple interactions, reflecting the complexity of the microbial processes involved within the rumen.

Introduction

Methane emissions by ruminant livestock have recently garnered interest as a significant source of greenhouse gasses, although livestock account for only 3.6% of greenhouse gas emissions in the United States or about one-third of all agriculture sources. Methane is one gas that contributes to total greenhouse gas emissions, and cattle account for 20% of U.S. methane. Despite the relatively small contribution of methane from cattle to total emissions, methane emissions from cattle should be a concern to producers not only from an environmental standpoint, but also because the production of methane represents an energetic loss to the animal. Diet is one of the main determinants of methane production, thus prompting recent work evaluating nutritional mitigation strategies. However, much of this work has been conducted on a small scale using intensive techniques such as respiration chambers or head boxes. Therefore, a method of gas collection and analysis was developed to allow evaluation of methane emissions by a large number of growing cattle under conditions that more closely mimic a production setting. The objective of this study was to evaluate the effect of forage quality, level of MDGS inclusion, and presence or absence of monensin on performance, methane concentration emitted by cattle, and ruminal VFA profile in growing calves and to determine the degree to which methane concentration and rumen fermentation characteristics are correlated.

Procedure

An 84-day growing study was conducted using 120 crossbred steers (initial BW = 661 ± 55 lb) that were individually fed using the Calan gate system. Five days before trial initiation, cattle were limit-fed a common diet of 50% alfalfa hay and 50% *Sweet Bran*® at 2% of BW to reduce variation in gut fill and then weighed on three consecutive days, with the average used as initial BW. Steers were stratified by initial BW and assigned randomly to one of 10 treatments based on the first two-day weights, with 12 steers per treatment. Six of these treatments (Table 1) were designed as a 2×2+2 factorial and were used in the analysis of performance. These diets consisted of four high-quality forage (blend of alfalfa and sorghum silage) diets with 0 or 40% MDGS and with or without monensin, and two low-quality forage (ground corn stalks) diets with 40% MDGS with or without monensin. Performance of cattle on the remaining treatments is discussed in the *2014 Nebraska Beef Cattle Report* (pp. 32-33. Methane and VFA measurements were collected on all 120 steers and all 10 treatments were used in those analyses. Steers were implanted with Ralgro on day 21. At the end of the study, cattle were again limit-fed the common diet for five days and weighed on three consecutive days to obtain ending BW.

To facilitate the collection of respired air by the cattle to be analyzed for methane and carbon dioxide, the individual Calan gate bunks were partially enclosed and outfitted with a small air pump that was used to gradually fill a gas collection bag. Gas collection was conducted at feeding, and gas sample bags were filled at a constant rate over approximately 10 minutes. Samples were collected only while steers were in their bunks. The

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Table 1. Composition of growing diets (DM basis).

	High-quality Forage				Low-quality Forage	
	0 MDGS[1]		40 MGDS		40 MGDS	
Monensin[2]	Y	N	Y	N	Y	N
Alfalfa	57	57	33	33	0	0
Sorghum silage	38	38	22	22	0	0
Corn stalks	0	0	0	0	55	55
MDGS	0	0	40	40	40	40
Supplement	5	5	5	5	5	5

[1]MDGS = modified distillers grains plus solubles.
[2]Diets with monensin were formulated to provide 200 mg/head/day.

collected gas consisted of a mixture of respired gasses and ambient air and was analyzed within 24 hours for concentration of methane and carbon dioxide in ppm using a gas chromatograph. Methane data are expressed as a ratio of methane to carbon dioxide (CH_4:CO_2) where CO_2 can be used as an internal marker since its production is relatively constant across cattle of similar size, type, and production level. Gas samples were collected from each steer a total of four times, about once every 21 days. Volatile fatty acid profile was evaluated using rumen fluid collected via esophageal tubing on day 21 and 63 prior to feeding. A portion of rumen fluid was also frozen and stored at -80° C for future microbial community analysis.

Additionally, VFA profile was used to estimate methane concentration in the theoretical fermentation balance equation proposed by Wolin, et al. 1960 (*Journal of Animal Science).* The predicted methane concentration was analyzed and compared to observed methane to carbon dioxide ratio. All data were analyzed using the Mixed procedure of SAS (SAS Institute, Inc., Cary, N.C.) with steer as the experimental unit. Methane and VFA data were analyzed using sampling point as the repeated measure.

Table 2. Effect of level of MDGS and presence of monensin on cattle performance in diets containing high-quality forage.

	0 MDGS		40 MDGS			*P*-value[1]		
Monensin	Y	N	Y	N	SEM	Level	Mon	Level*Mon
Initial BW, lb	660	663	661	658	7.0	0.80	0.99	0.67
Ending BW, lb	822	836	959	931	11.6	<0.01	0.53	0.08
DMI, lb/day	19.6	19.5	22.8	21.9	0.75	<0.01	0.53	0.60
ADG, lb	1.93[d]	2.06[c]	3.55[a]	3.25[b]	0.09	<0.01	0.34	0.02
F:G	10.2[c]	9.5[b]	6.5[a]	6.8[a]	0.23	<0.01	0.47	0.03

[1]*P*-value: Level = main effect of MDGS inclusion level, Mon = main effect of presence of monensin, Level*Mon = effect of interaction between level and monensin.
[a,b,c,d]Means in a row with different superscripts are different ($P < 0.05$).

Table 3. Effect of forage quality and presence of monensin on cattle performance in diets containing 40% MDGS.

	High-quality forage		Low-quality forage			*P*-value[1]		
Monensin	Y	N	Y	N	SEM	Forage	Mon	Forage*Mon
Initial BW, lb	661	658	663	663	7.6	0.67	0.81	0.88
Ending BW, lb	959	931	809	814	12.2	<0.01	0.35	0.17
DMI, lb/day	22.8	21.9	13.7	14.5	0.45	<0.01	0.96	0.07
ADG, lb	3.64	3.34	1.83	1.91	0.19	<0.01	0.27	0.07
F:G	6.5	6.8	8.2	8.2	0.34	<0.01	0.58	0.65

[1]*P*-value: Forage = main effect of forage quality, Mon = main effect of presence of monensin, Forage*Mon = effect of interaction between forage quality and monensin.

Table 4. Effects of MDGS level and monensin in high-quality forage diets.

	0 MDGS		40 MDGS			*P*-value[1]		
Monensin	Y	N	Y	N	SEM	MDGS	Mon	MDGS*Mon
CH_4:CO_2	0.101	0.104	0.100	0.102	0.003	0.69	0.39	0.74
Total VFA, Mm	36.3	38.3	32.2	43.6	2.86	0.82	0.02	0.10
Acetate, mol/100 mol	71.3	72.8	66.8	67.2	0.48	<0.01	0.04	0.23
Propionate, mol/100 mol	15.2	14.5	17.7	17.0	0.42	<0.01	0.11	0.98
Butyrate, mol/100 mol	8.4[b]	7.9[b]	8.7[b]	9.7[a]	0.29	<0.01	0.33	<0.01
Acetate:Propionate	4.78	5.05	3.81	3.99	0.12	<0.01	0.06	0.70
Theoretical mol CH_4[2]	35.9	36.6	32.9	33.8	0.24	<0.01	<0.01	0.69

[1]*P*-value: MDGS = main effect of MDGS inclusion level, Mon = main effect of presence of monensin, MDGS*Mon = effect of interaction between level of MDGS and monensin
[2]Calculated mol of methane produced per 100 mol VFA
[a,b,c]Means in a row with different superscripts are different ($P < 0.05$).

Results

Steers fed diets based on high-quality forage were 134 lb heavier at the end of the growing period than those fed low-quality forage based diets ($P < 0.01$; Table 3). Cattle fed 40% MDGS in high-quality forage diets had heavier ending BW than those consuming no MDGS ($P < 0.01$; Table 2). This is not surprising considering cattle on high-quality forage diets also consumed 37% more DM, had greater ADG, and were more efficient than cattle consuming low-quality forage ($P < 0.01$). When comparing steers fed high-quality forage diets, those consuming 40% MDGS had greater DMI and ADG; and lower F:G than those not receiving MDGS ($P < 0.01$). A MDGS level by monensin interaction was observed for ADG ($P = 0.02$) and F:G ($P = 0.03$) in high-quality forage diets. Presence of monensin in the diet improved ADG and had no effect on F:G in diets containing 40% MDGS. However, in the absence of MDGS, monensin decreased ADG and resulted in poorer efficiency ($P < 0.05$). No effect due to monensin was observed when comparing only diets containing 40% MDGS (Table 3).

Methane to CO_2 ratio was not affected by inclusion level and oil content of MDGS or by presence of monensin in high-quality forage diets (Table 4). However, in diets with 40% MDGS, a forage quality x monensin interaction was observed ($P = 0.02$, Table 5). Monensin had no effect on CH_4:CO_2 in high-quality forage, but decreased CH_4:CO_2 by 16% in low-quality forage diets. Using actual VFA profile in the prediction equation of Wolin generates a theoretical production of methane in moles of CH_4 /100 mol of total VFA concentration. Measurement of total VFA production was not possible in the current study, but this estimated value may be of some value to compare with our observed CH_4:CO_2. In high-quality forage diets, presence of both MDGS and monensin decreased theoretical CH_4 ($P < 0.01$), whereas no effect was observed in CH_4:CO_2.

Table 5. Effects of forage quality and monensin in diets containing 40% de-oiled MDGS.

	High-quality forage		Low-quality forage			P-value[1]		
Monensin	Y	N	Y	N	SEM	Forage	Mon	Forage*Mon
CH_4:CO_2	0.101	0.102	0.083	0.099	0.003	<0.01	<0.01	0.02
Total VFA, Mm	32.2[b]	43.5[a]	38.6[a,b]	38.7[a,b]	2.65	0.76	0.04	0.04
Acetate, mol/100 mol	66.9	67.3	70.8	70.8	0.56	<0.01	0.73	0.69
Propionate, mol/100 mol	17.7	17.1	17.8	17.9	0.34	0.20	0.51	0.24
Butyrate, mol/100 mol	8.6	9.7	5.8	6.6	0.24	<0.01	<0.01	0.54
Acetate:Propionate	3.81	3.97	4.01	3.96	0.093	0.30	0.54	0.24
Theoretical mol CH_4[2]	33.0	33.8	33.6	34.0	0.24	0.09	0.01	0.28

[1]*P*-value: Forage = main effect of forage quality, Mon = main effect of presence of monensin, Forage*Mon = effect of interaction between forage quality and monensin
[2]Calculated mol of methane produced per 100 mol VFA
[a,b,c]Means in a row with different superscripts are different ($P < 0.05$).

Table 6. Effects of type and level of MDGS in diets containing low-quality forage and monensin.

	De-oiled		Normal			P-value[1]		
	20 MDGS	40 MDGS	20 MDGS	40 MDGS	SEM	Type	Level	Type*Level
CH_4:CO_2	0.084	0.083	0.086	0.082	0.004	0.96	0.43	0.64
Total VFA, Mm	32.6	38.5	38.9	32.2	3.15	0.99	0.90	0.05
Acetate, mol/100 mol	71.8	71.0	71.7	72.1	0.62	0.41	0.70	0.35
Propionate, mol/100 mol	17.6[a]	17.8[a]	18.3[a]	15.7[b]	0.42	0.09	<0.01	<0.01
Butyrate, mol/100 mol	6.7	5.8	6.3	6.0	0.169	0.51	<0.01	0.12
Acetate:Propionate	4.10[b]	4.02[b]	3.95[b]	4.72[a]	0.160	0.09	0.03	0.01
Theoretical mol CH_4[2]	34.7[a]	33.7[b]	34.3[a,b]	34.9[a]	0.35	0.25	0.48	0.03

[1]*P*-value: Type = main effect of type of MDGS (De-oiled or Normal), Level = main effect of level of MDGS inclusion, Type*Level = effect of interaction between type and inclusion of MDGS.
[2]Calculated mol of methane produced per 100 mol VFA.
[a,b,c]Means in a row with different superscripts are different ($P < 0.05$).

The Wolin equation also predicted a decrease in CH_4 due to monensin in diets containing MDGS, which agrees with observed CH_4:CO_2. Future work is planned to improve use of prediction equations, and to estimate CO_2 production, which will be used to convert CH_4:CO_2 to a more useful methane production value.

Total Mm concentration of VFA in rumen fluid collected in this study is lower than may have been expected. This is likely due to time of sampling, as cattle were tubed in the morning prior to feeding and had relatively low DMI compared to VFA concentrations that would be seen in finishing cattle on full feed. In diets containing 40% MDGS, steers fed high-quality forage had decreased acetate and increased butyrate concentrations ($P < 0.01$). This is indicative of fermentation of more digestible fiber compared to low-quality forage. Forage quality did not affect acetate to propionate ratio ($P = 0.30$). In high-quality forage based diets, inclusion of 40% MDGS also decreased acetate, increased propionate, and decreased acetate to propionate ratio ($P < 0.01$), as would be expected with the addition of an increase in total diet digestibility. Monensin tended ($P = 0.06$) to decrease acetate to propionate ratio in these diets as well, while presence of MDGS negated the effect of monensin on acetate to propionate ratio. A type of MDGS (de-oiled or normal) x inclusion level interaction was observed for propionate concentration ($P < 0.01$) and acetate to propionate ratio ($P = 0.01$). Increasing de-oiled MDGS from 20 to 40% of diet DM had no effect, while increasing inclusion of normal-fat MDGS actually decreased propionate and increased acetate to propionate ratio. This unexpected result may be due to the high fiber nature of these diets, where added fat may inhibit digestibility.

These data represent the first effort into a new area of research for our group. Work is ongoing to refine both the methods used for collecting methane in this setting, and the calculations used to generate meaningful estimates of methane emissions. These data suggest that methane concentration by growing cattle can be manipulated by diet composition. Differences in forage type and the inclusion of MDGS and monensin did appear to influence ruminal fermentation, and as a result methane concentration.

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