Methane Production, Diet Digestibility, and VFA Profile of Growing Steers Fed High or Low Quality Forage

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Summary

A headbox calorimeter study evaluated the impacts of forage quality on methane production, diet digestibility, and VFA profile of growing steers. Daily production of methane and carbon dioxide were greater for steers fed high-quality compared to low-quality forages. There was no difference in DM or OM digestibility, likely due to dramatic intake differences, and no difference in the amount of methane produced per unit of OM digested. Methane emissions data from this study agree reasonably well with those obtained by alternate methods previously utilized by this group.

Introduction

Methane production through enteric fermentation by ruminants is a nutritional as well as an environmental concern. Forage is the primary component in diets fed to beef cattle. There is a vast array of forages available and forages vary widely in quality, often measured as differences in fiber (NDF) content. This variation in forage characteristics can have a significant impact on animal performance and CH_4 emissions due to differences in digestibility and resulting VFA profile. Therefore, the objective of this experiment was to determine the impact of forage quality in growing diets on methane production using indirect calorimetry; and to compare results with those obtained by a less intensive method described previously (*2014 Nebraska Beef Cattle Report*, pp. 29–31).

Procedure

Six intact, crossbred steers (initial BW 813 lb; SD = 37 lb) were used in a 3-period switchback designed, calorimetry study to evaluate CH_4 production by growing cattle consuming low- or high-quality forage. Steers were paired by similar BW and assigned randomly within pair to one of two treatments for three, 21-d periods, with a 4-d fecal sample collection period and two consecutive, 23-h periods in the headbox calorimeter. Two treatments were designed to be similar to a previous study (*2014 Nebraska Beef Cattle Report*, pp. 29–31): a high-quality forage diet consisting of a 60:40 sorghum silage:alfalfa hay blend with 20% MDGS (HQ) or a low quality forage diet consisting of 75% ground corn stalks and 20% MDGS (LQ), each with 5% supplement. Urea was included in the LQ diet at 1.65% and both treatments were formulated to provide 200 mg/steer daily of monensin (Rumensin, Elanco Animal Health). Nutrient composition of the HQ diet was: 14.8% CP, 50.5% NDF, and 37.1% ADF. The nutrient composition of the LQ diet was: 13.9% CP, 68.3% NDF, and 48.3% ADF. Steers were fed *ad libitum* once daily at 0800. Feed refusals were weighed back daily and on d 10–14, weighed, subsampled, and dried at 60°C for DM determination.

Apparent total tract digestibility of DM, OM, NDF, and ADF were determined through total fecal collection using fecal bags on d 12–15. Feces were weighed, mixed, and composited by day and steer for DM determination. Steer by period composites of feces, feed ingredients, and feed refusals were dried, ground, and analyzed for DM as described above. All samples were ashed at 600°C for 6 h for OM determination. In addition, NDF and ADF analyses were performed on all samples using the ANKOM system. Rumen fluid was collected on the morning of day 20, prior to feeding, and analyzed for VFA profile.

Methane emissions were measured through indirect calorimetry using headboxes constructed at the University of Nebraska-Lincoln with the guidance of the U.S. Meat Animal Research Center (Clay Center, NE). Steers were trained and acclimated to the headboxes before the initiation of the study. Only two headboxes were available, so the start day of the trial for each pair of steers was offset. Methane collections consisted of two consecutive, 23-h periods on d 20 and 21 of each period. Feed offered continued to be called and adjusted throughout all collections, with the goal of *ad libitum* access. Steers and feed were placed in the headboxes at approximately 0800 and the doors were closed and vacuum motor turned on for 15 minutes before collections commenced to allow for air equilibration. Total gas flow through the system was measured using a flowmeter and a constant, proportional sample of inlet and exhaust air was sampled and regulated using flowmeters. Gas samples were collected in methane gas collection bags and analyzed for CH_4 and CO_2 using a gas chromatograph. Steers were removed from headboxes for one hour between the two collection days to rest in their home pens and allow for cleaning and removal of refused feed.

Nutrient intake and digestibility as well as CH_4 and CO_2 production were analyzed using the MIXED procedure of SAS (SAS Inst., Cary, NC) with period and treatment as fixed effects and steer as the random effect. An α-level of $P \leq 0.10$ was considered significant.

Results

Digestibility

Intake of DM, OM, and ADF were greater for cattle fed HQ compared to LQ forage ($P \leq 0.01$, Table 1), with DMI of HQ forage being 48% greater than that of LQ forage. Intake of NDF also tended to be greater when steers consumed HQ forage ($P = 0.06$). Apparent total tract digestibility of DM tended ($P = 0.08$) to be greater for those cattle fed HQ compared to LQ forage (63.7 and 61.5% respectively). No differences were observed for OM digestibility ($P = 0.59$). Both NDF and ADF digestibilities were greater in cattle fed diets containing LQ forage compared to HQ ($P < 0.01$). As expected, cattle fed the alfalfa hay and sorghum silage blend ate more than those fed ground corn stalks. Greater intakes of

Table 1. Intake and digestibility of steers fed diets containing high or low quality forage.

Item	Treatment[a]		SEM	*P*-value
	HQ	LQ		
Intake, lb/d				
DM	21.6	14.6	0.57	< 0.01
OM	19.6	13.5	0.51	< 0.01
NDF	10.6	9.7	0.35	0.06
ADF	7.7	6.8	0.22	0.01
Apparent total tract digestibility, %				
DM	63.7	61.5	1.15	0.08
OM	66.0	66.7	1.07	0.59
NDF	54.6	64.2	1.27	< 0.01
ADF	49.5	58.7	1.49	< 0.01

[a]HQ = diets containing high-quality forage; LQ = diets containing low-quality forage.

Table 2. Methane emissions and VFA profile of steers fed diets containing high or low quality forage.

Item	Treatment[a]		SEM	*P*-value
	HQ	LQ		
Emissions				
CH_4:CO_2	0.090	0.082	0.002	0.03
CH_4, L/d	210	132	6.6	< 0.01
CH_4, L/lb OM digested	16.1	14.9	0.59	0.14
CO_2, L/d	2404	1654	76.4	< 0.01
VFA profile				
Acetate, mol %	66.3	67.6	1.02	0.22
Propionate mol %	19.5	19.8	0.95	0.82
Butyrate, mol %	10.1	8.8	0.61	0.05
Acetate: Propionate	3.4	3.5	0.22	0.94

[a]HQ = diets containing high-quality forage; LQ = diets containing low-quality forage.

DM, OM, NDF, and ADF by those steers consuming HQ forage could be attributed to the increased passage rate and reduced gut fill limitation associated with a diet that contains less NDF (50.5 vs. 68.3) and ADF (37.1 vs. 48.3) than the LQ forage. The tendency for the small increase in DM digestibility in HQ compared to LQ forage is not the magnitude of response expected. However, the large difference in DMI (48% greater for HQ) may have led to similar digestibility estimates, presumably due to a slow passage rate for LQ forage. In addition, NDF values are not ash corrected which may impact absolute values of NDF in the LQ treatment. Even so, digestibility for LQ forage was greater than anticipated. Similarly, we expected to observe a lower OM digestibility for cattle fed LQ forage, as would be indicated by performance of those fed a similar diet (*2014 Nebraska Beef Cattle Report*, pp. 29–31). The digestibility data are potentially due to the dramatic difference in DMI, especially considering that steers fed HQ forage had intakes approaching 3% of BW.

Methane Emissions and VFA Profile

Cattle consuming HQ forage had greater CH_4:CO_2 ($P = 0.03$, Table 2) than those fed LQ forage (0.090 vs. 0.083). Methane and CO_2 production (L/d) were also greater ($P < 0.01$), with cattle fed HQ forage producing 59 and 43% more than those consuming LQ forage, respectively. However, due to the 31% decrease in OM intake in LQ vs. HQ forage diets, no difference was observed for CH_4 production per lb of OM digested ($P = 0.14$). Increasing forage quality, as defined by decreasing fiber content impacts CH_4 production by decreasing acetate production, which has traditionally been associated with lower observed CH_4 production. However, we did not observe the expected differences in methane production due to forage quality. In this study, HQ forage increased both daily CH_4 production and CH_4:CO_2, the latter of which should account for differences due to DMI. It is important to remember, however, that although HQ forage results in greater daily CH_4 production, cattle fed LQ forage gain less weight, negating savings in daily CH_4 production on a weight gain basis.

Forage quality had no impact on molar proportion of acetate or propionate ($P = 0.22$ and $P = 0.82$, respectively; Table 2). Thus, A:P was not different, 3.4 vs 3.5 in HQ and LQ forage diets ($P = 0.94$). Concentration of butyrate was greater in those cattle consuming HQ forage ($P = 0.05$). An increase in total VFA concentration could be expected but total VFA production was not measured in this study, and total mM concentration of VFA is not reported as the concentration is not indicative of VFA production and sampling method used in this study is not ideal for measuring total VFA concentration due to potential saliva contamination (esophageal tubing). Additionally, no differences in VFA profile is likely due to the time of rumen fluid collection, which was in the morning prior to feeding, when VFA profile is least impacted due to diet quality.

A major objective of this work was to compare methane emissions values obtained by our system described in the *2014 Nebraska Beef Cattle Report*, pp. 29–31, with those obtained in this study using indirect calorimetry. A comparison of emissions values for cattle fed high and low-quality forage, obtained through each

system is presented in Table 3. While the absolute values may not agree, we consider the relative differences as well as the direction of change between treatments, to be in reasonable agreement. The newly developed system appears to be capable of detecting differences, at least of the magnitude displayed in this comparison, though HQ and LQ forage treatments were chosen specifically for their expected differences in CH_4 production.

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Table 3. Comparison of emissions data obtained through methods described in *2014 Nebraska Beef Cattle Report*, pp.29–31 or by calorimetry in the current study

Item	Treatment[a]	
	HQ	LQ
CH_4:CO_2		
Headbox[b]	0.090	0.082
Calan[c]	0.101[d]	0.088
CH_4, L/d		
Headbox	210	132
Calan	224–345[d]	125
CO_2, L/d		
Headbox	2404	1654
Calan	2210–3447[d]	1421
DMI, lb		
Headbox	21.6	14.6
Calan	19.6–22.7[d]	10.8

[a]HQ = diets containing high-quality forage; LQ = diets containing low-quality forage.
[b]Values obtained in current, through indirect calorimetry.
[c]Values obtained in *2014 Nebraska Beef Cattle Report*, pp. 29–31.
[d]A range is shown for values obtained in Exp. 1 because an exact diet comparison is not available. High-quality forage diets in Calan gate barn contained 0 or 40% modified distillers grains plus solubles; those in the current study contained 20%.