Evaluation of Methane and CO_2 Production in Growing and Finishing Cattle Raised in Conventional or Partial Confinement-based Herds

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Summary with Implications

Methane emissions from growing and finishing calves compared either a spring calving, conventional cow system or a summer calving, partially-confined cow system. Calves weaned from the confinement-based production system were smaller at weaning and compensated with greater gain during the growing phase. More days on feed in the finishing phase were needed for the calves from the confinement system to reach same backfat thickness. Over the entire growing and finishing phases, calves from the confinement-based system produced more total CH_4 and CH_4 per lb. HCW. Production of methane and CO2 per lb. of gain was lower in calves from the confinement system in the growing phase. During the finishing period, calves from the conventional system had greater daily gain and lower methane per lb. of gain. Cattle consuming finishing diets had less CH_4 per lb. feed intake and feeding growing diets resulted in less CO_2 per animal per day and per lb. feed intake. Differences in GHG emissions were a function of size, feed intake, growth rate and diet composition.

Introduction

The production of beef is scrutinized due to production of greenhouse gases (GHG), particularly enteric methane. Previous work has shown that cattle naturally produce methane (CH_4). There is a positive correlation between CH_4 production and dry matter intake (DMI) and forage intake, and a negative correlation with concentrate inclusion. Diets containing high levels (>40%) of forage result in greater CH_4 production per lb. of intake, per calorie of energy intake, and lb. of gain or production, but not necessarily per animal per day. Carbon dioxide (CO_2) is also a GHG produced by cattle due to respiration. While not as potent as CH_4, a greater understanding of CO_2 production is important when quantifying total GHG production of beef systems. But many times, CO_2 production is ignored in GHG budgeting. Although GHG production by cattle consuming diets of various quality has been measured, there are no known comparisons of GHG from cattle of similar genetics originating from different cow/calf production systems.

The objective of this study was to measure post-weaning GHG production from calves raised in different beef systems when consuming a high forage growing diet or a high concentrate finishing diet. Comparisons were made between the diets, and the systems for total GHG production and various measures of animal production and performance.

Procedure

The GHG emissions from progeny from two cow/calf confinement systems were evaluated. At the onset of the trial, 160 cows were assigned randomly to one of 2 production systems, Conventional (CONV) and Alternative (ALT). Cow age was equally represented in both systems. In each system, 4 groups of cows (n=20) were raised under set conditions for 2 consecutive years, and post-weaning practices remained the same for all calves (steers and heifers). The CONV system was a pasture-based system. Cow/calf pairs grazed bromegrass pastures from April 25 to October 15, calved between April 15 and June 15 and weaned October 15 when calves were approximately 168 days of age. After weaning, cows grazed corn residue until March 15, then returned to grass pastures and were fed grass hay until forage growth was adequate for grazing. The ALT system was an intensive, feedlot-based system during the summer and grazing during the fall and winter. Cows entered the feedlot on March 15 and were limit-fed from March 15 until calving which occurred July 15 to September 15. Cow feed intakes were adjusted to meet gestation and lactation needs according to a well-established beef cattle model. After calving, cow/calf pairs grazed secondary annual forage from October 15 to January 15, when calves were weaned. Calves from both systems were fence-line weaned for 5 days and limit-fed at 2% of bodyweight (BW) a diet of 50% alfalfa hay and 50% Sweet Bran (DM-basis). Cattle were weighed 2 consecutive days before starting a growing period (113 d year 1, 120 d year 2) and fed 35% grass hay, 30% modified distillers grains plus solubles, 30% dry-rolled corn, and 5% supplement (DM basis) for *ad-libitum* intake (Table 1). When the growing period ended, cattle were limit-fed at 2% BW a diet of 50% alfalfa and 50% Sweet Bran for 5 consecutive days and weighed 2 consecutive days to determine initial body weight for the finishing phase. Following weighing, cattle were adapted to a high grain finishing diet using 4 step up diets over 24 days and finished to a target of 0.5 inches of backfat projected using 2 ultrasound measurements over the feeding period. The finishing diet in year 1 was 34% dry-rolled corn, 34% high-moisture corn, 20% modified distillers grains plus solubles, 7% grass hay, and 5% supplement (DM basis), and in year 2, 40% HMC, 40% Sweet Bran, 15% corn silage, and 5% supplement (DM basis). Two years of calf crops from both CONV and ALT were monitored during growing and finishing phases.

During both growing and finishing, each pen of calves was put into a double-sided pen-scale GHG measurement barn chamber for 5 consecutive days. Methane and CO_2 were monitored through a negative pressure system. The barn contains 2 methane chambers that are completely enclosed and separated from each other. Each chamber contains two fans to pull

Table 1. Composition of diets (DM basis) fed to cattle during growing and finishing phases.

	Growing	Finishing	
Ingredient, % DM	Years 1 and 2	Year 1	Year 2
Dry rolled corn	30	34	
High moisture corn		34	40
Sweet Bran			40
Modified distillers grains	30	20	
Corn silage			15
Grass hay	35	7	
Supplement	5	5	5
Fine ground corn	2.52	2.29	1.88
Limestone	1.98	1.69	1.63
Tallow	0.13	0.13	0.1
Urea	0	0.5	0
Salt	0.30	0.30	0.30
Beef trace mineral	0.05	0.05	0.05
Vitamine ADE premix	0.015	0.015	0.015
Rumensin 90 premix	0.012	0.017	0.017
Tylan 40 premix	0	0.011	0.010

air through at a rate of 2,789 $feet^3$/minute. Sampling ports are located near the fans, with pumps that pull air into a sampling line. The air is analyzed using two open path lasers, the LI-COR 7500 for CO_2 and the LI-COR 7700 for CH_4. The air sampling system cycles between 3 sampling lines; one line in each chamber (east and west) and one line on the south side for ambient air supply. Each cycle lasts 20 minutes during which each side of the barn and ambient air are sampled.

Calves from one pen were split evenly between both chambers of the barn after sorting to equalize heifers and steers in each chamber. After 5 days, calves were removed, and the manure that accumulated over the previous 5 days was monitored for GHG emissions for 24 hours. On the 7^{th} day, manure was removed from the barn using a skid loader and then a final 24 hours measurement of the empty barn with no manure or cattle was performed for baseline measurements. The GHG production from manure was calculated by the difference from baseline. It was assumed that the GHG contributions from manure were equal to one-half of what was measured during the 24 hours, since, on average, half of the accumulated manure was present in the barn at any one time during the 5-day measurement period. The GHG contribution from manure was subtracted from the total GHG emissions to determine GHG emissions from the cattle. This correction was small, averaging 1.32 grams of CH_4 and 130 grams of CO_2 per animal per day. When the 7-day cycle was complete, the cycle was repeated for the other 3 reps in the production system. Calves from both CONV and ALT systems were in the barn for the same days on feed within year, on average, for both growing and finishing, but were at different times of the year between systems due to differing calving dates.

Total GHG production (grams/animal daily) was analyzed as an ANOVA using PROC MIXED, with day in barn as the repeated measure. There were 5 days of measurements each time cattle were in the barn. The means of the 5 days for of CO_2 and CH_4 production from each chamber were used to calculate GHG production from each replicate within groups. These were used to calculate CO_2 and CH_4 emissions expressed per lb. of intake. The CO_2 and CH_4 values per lb. of DMI were used to calculate grams of CO_2 and CH_4 per lb. of gain, per animal daily, and the total over the entire feeding period. Cattle in CONV and ALT were slaughtered at equal backfat thicknesses, but groups had different numbers of days on feed and different feed intakes. Differences in CH_4 and CO_2 production were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit and year as a random variable.

Results

Production Systems

Cattle consuming the growing diet did not differ in DMI between CONV and ALT (Table 2). Calves from the ALT system had greater ADG and lower F:G ($P < 0.01$) during the growing period compared to CONV. Greater CH_4 and CO_2 production per lb. of ADG ($P < 0.01$) and a tendency for greater CO_2 production over the entire growing period ($P = 0.07$) were observed in CONV calves. During the finishing phase there were no differences in DMI ($P = 0.25$); however, CONV calves had greater ADG and reduced F:G ($P < 0.01$). Due to the difference in ADG, CONV calves had lower CH_4 emissions per lb. of ADG ($P = 0.01$) during finishing. CONV calves had less total CO_2 per animal ($P = 0.02$) during finishing. Over the entire growing and finishing period CONV calves had less CH_4 per lb. HCW ($P = 0.04$) and less total CH_4 ($P = 0.02$). There were no differences in carcass adjusted final BW, HCW, ADG, DMI, or F:G over the combined growing and finishing period ($P = 0.15$). Cattle in ALT system were approximately 100 lb. lighter at the start of growing but were fed, on average, 35 days longer during finishing. This explains the differences in ADG but lack of differences in final BW and HCW.

Table 2. Performance and greenhouse gas production by cattle raised in conventional (CONV) or alternate (ALT) partial confinement production systems.

	CONV	ALT	SEM	*P value*
Growing Phase				
DMI, lb./day	19.6	19.1	0.25	0.15
ADG, lb.	2.67	3.05	0.04	<0.01
F:G	7.35	6.25	-	<0.01
Days, n	116	116		
CH_4 Production				
Per animal per day, g	122.9	121.9	3.42	0.79
Per lb. DMI, g	7.31	7.14	0.24	0.62
Per lb. ADG, g	53.7	44.8	2.53	<0.01
Total per animal, lb.	632.3	558.2	36.4	0.06
CO_2 Production				
Per animal per day, g	4713	4948	193	0.25
Per lb. DMI, g	297.8	271.9	12.9	0.18
Per lb. ADG, g	2188	1702	135	<0.01
Total per animal, lb.	25779	21233	1812	0.03
Finishing Phase				
DMI, lb./day	23.31	23.83	0.43	0.25
ADG, lb.	3.99	3.34	0.07	<0.01
F:G	5.88	7.13	-	<0.01
Days, n	148	183		
CH_4 Production				
Per animal per day, g	125.1	145.1	11.3	0.10
Per lb. DMI, g	5.34	6.07	0.46	0.14
Per lb. ADG, g	31.7	43.2	4.45	0.02
Total per animal, lb.	687.8	910.5	114.4	0.07
CO_2 Production				
Per animal per day, g	7576	7101	345	0.19
Per lb. DMI, g	326.2	299.7	15.2	0.11
Per lb. ADG, g	2009	2138	79	0.13
Total per animal, lb.	42384	44359	3045	0.53

Diets

Shown in Table 3, there was greater DMI the finishing period ($P < 0.01$), and there was a production system by diet interaction for F:G and ADG ($P < 0.01$). The interaction is explained by greater ADG in the growing period by calves in the ALT system and greater ADG in the finishing period by calves in the CONV system. With no differences in DMI this resulted in an interaction in F:G. At weaning calves from ALT system were 100 lbs. lighter than calves in the CONV system and compensatory growth occurred in the growing phase. Subsequently, calves from CONV system had greater ADG in the finishing phase ($P < 0.01$). There was a system by diet interaction for both CH_4 and CO_2 per lb. of ADG ($P < 0.01$). There was greater DMI when calves consumed a finishing diet, however, there were more CH_4 emissions during growing per lb. DMI ($P < 0.01$). One explanation is the greater forage content of the growing diet that led to greater CH_4 per lb. of DMI (7.23 vs 5.71 grams per lb. DMI). The opposite is true for CO_2. When consuming the finishing diet, cattle produced more CO_2 per animal per day ($P < 0.01$) and a tendency for more CO_2 per lb. DMI ($P = 0.06$). This was likely due to more CO_2 generated from metabolism in finishing cattle that were, on average, heavier than cattle consuming a growing diet.

Conclusion

Cattle raised in a partial-confinement cow/calf production system and born in the summer produced 17% less total CH_4 and 22% less total CO_2 per lb. of ADG when consuming a growing diet compared to calves raised in a conventional, grass-based system. The data from the study suggests that this was due to differences in BW, DMI and ADG. Cattle consuming a forage-based growing diet produced 21% more CH_4 and 9.8% less CO_2 per lb. of dietary intake compared to a grain-based diet. However, cattle consuming a grain-based diet produced 24% less CH_4 and 6.5% more CO_2 per lb. of ADG. During the finishing phase, cattle raised in the confinement-based system produced 14% more total CO_2 and 46% more total CH_4 because of more days on feed. Over the entire growing and finishing

Table 2. Continued

	CONV	ALT	SEM	*P value*
Growing and Finishing Phases				
Initial BW, lb.	508	409	8.7	<0.01
Carcass adjusted Final BW, lb.	1333	1356	17	0.19
HCW, lb.	840	855	11	0.18
DMI, lb./day	21.7	21.9	0.3	0.45
ADG, lb.	3.38	3.22	0.1	0.15
F:G	6.49	6.80	-	0.16
CH_4 Production				
Per lb. DMI, g	6.13	6.44	0.27	0.27
Per animal per day, g	132.8	141.5	6.24	0.18
Total per animal, lb.	77.3	94.5	6.5	0.02
Per lb. HCW, g	41.8	50.2	3.76	0.04
CO_2 Production				
Per lb. DM, g	315.2	290.0	13	0.07
Per animal per day, g	6816	6341	252	0.08
Total per animal, lb.	3984	4180	158	0.23
Per lb. HCW, g	2153	2226	99	0.47

Table 3. Performance and greenhouse gas production of cattle consuming growing or finishing diets.

				P value		
	Growing	Finishing	SEM	Diet	System	Diet x System
DMI, lb.	19.3	23.5	0.3	<0.01	0.95	0.10
ADG, lb.	2.86	3.66	0.14	<0.01	0.36	<0.01
F:G	6.76	6.44	1.4	0.19	0.59	<0.01
CH_4 Production						
Per animal per day, g	139.7	135.1	8.23	0.59	0.43	0.11
Per lb. DM	7.23	5.71	0.34	<0.01	0.42	0.19
Per lb. ADG	49.2	37.50	2.6	<0.01	0.63	<0.01
CO_2 Production						
Per animal per day, g	5506	7339	277	<0.01	0.05	0.76
Per lb. DM	284.9	313.0	28.1	0.06	0.08	0.99
Per lb. ADG	1945	2073	118	0.29	0.14	0.01

period calves raised in a confinement-based system produced 22% more CH_4 and 20% more CH4 per lb. HCW. Differences in diet composition, rates of gain, and days on feed impact GHG emissions, which impacts total GHG emission prior to harvest.

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