Impact of Limit Feeding Finishing Beef Steers on Enteric Methane Production and Animal Performance

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Abstract
The impact ruminants have on environmental sustainability has been a growing concern in recent decades. Many cattle in the northern Great Plains are fed on family-owned farms and feedlots, highlighting the need for producer-friendly mitigation strategies, such as the established, but not widely adopted, management strategy of controlled or limit feeding. The objective of this experiment was to determine the impact of limit feeding on enteric methane (CH_4) production and subsequent animal performance. Angus-cross steers (n = 48, body weight [BW] = 985 ± 9.7 lb) were blocked by BW and assigned to one of three treatment groups. Treatments consisted of a 1) control (CON) where steers were fed *ad libitum*; 2) Treatment 1 (TRT1) where steers were fed 96% of *ad libitum*; and 3) treatment 2 (TRT2) where steers were fed 92% of *ad libitum*. Once weekly, TRT1 and TRT2 were adjusted based on the CON steers' average intakes from the previous week. The BW was measured monthly and dry matter intake (DMI; lb/day) was measured using an Insentec Roughage Intake Control System (Insentec, Markenesse, The Netherlands). Enteric CH_4 and carbon dioxide (CO_2) production were determined utilizing two GreenFeed emission measurement systems (Automated Head-Chamber System; C-Lock Inc., Rapid City, SD). Only visits greater than 3 minutes in duration were used for analysis. Average daily gain and gain to feed did not differ among treatments ($P = 0.15$ and $P = 0.75$, respectively). The DMI was greatest for CON and least for TRT2 ($P \leq 0.01$). The CH_4 (g/day) output differed between treatments ($P \leq 0.007$). There was a tendency for a quadratic relationship for methane yield (g/lb DMI) among treatments ($P = 0.06$). Emission intensity (g CH_4/lb gain) was not different across treatments ($P = 0.78$). These results suggest precision feeding may have a positive impact on methane emissions and methane yield.

Introduction
Over recent decades, the impact of human-induced climate change and the role of ruminant agriculture has been of growing concern for both the general public and the scientific community. Of particular interest is methane (CH_4) produced as a byproduct of reticulo-rumen fermentation, which is a potent greenhouse gas with a global warming potential of 28 times that of carbon dioxide (CO_2) over a 100-year time horizon and is responsible for 30% of the CH_4 budget in the U.S. (EPA, 2021). The production of this gas and its mitigation is an old energetics question that, in recent decades, has taken a new dimension because of its potent energy-trapping potential in the atmosphere (Hristov et al., 2022). Mitigation strategies are needed that ideally

reduce emissions from all sources, or at a minimum, do not increase other emission sources through their respective mode of action. Additionally, strategies need to be producer-friendly by being easy to adopt and ideally increase their economic returns via improvements in efficiency/animal performance (Thompson and Rowntree, 2020). The concept of restricting feed intake is a long-established management strategy in the literature and comes in various forms including restricted feeding (where intake is restricted based on the amount of anticipated intake), programmed feeding (based on net energy equations to calculate intake levels), and also limit feeding (Plegge, 1986; Galyean et al., 1999). Although generally, as animals increase energy consumption feed efficiency is improved, previous research indicates that maximum feed intake does not equal maximum feed efficiency (Gill et al., 1986). The objective of this experiment was to determine the impact of increasing feeding amounts on enteric CH_4 emissions and subsequent animal performance in finishing beef steers.

Experimental Procedures

Prior the experiment, 70 steers were shipped from an auction house in southern Missouri to the Kansas State University Beef Cattle Research Center. On arrival, animals were held overnight with fresh water, fed a 50 net energy for gain receiving ration, and underwent initial processing the following morning. Animals were acclimated to an Automated Head-Chamber System (AHCS) for approximately 30 days and then acclimated to a pen and acclimated to 14 Insentech Roughage Intake Control feeders (Insentec, Markenesse, The Netherlands) for an additional 28 days. After the additional acclimation period, 48 steers were selected (body weight [BW] = 985 ± 9.7 lb) based on equipment acclimation, weighed, and were blocked by weight into one of three treatment groups, for a total of 16 animals per treatment. On day 0, all steers were weighed and implanted with Synovex Plus (200 mg trenbolone acetate plus 28 mg estradiol). During the experiment, three steers were removed from the study due to refusal to use the Insentec system.

Treatments consisted of a 1) control (CON) where steers were fed *ad libitum*; 2) Treatment 1 (TRT1) where steers were fed 96% of *ad libitum*; and 3) treatment 2 (TRT2) where steers were fed 92% of *ad libitum*. Once weekly, TRT1 and TRT2 were adjusted based on the CON steers' average intakes from the previous week. To minimize animal-to-animal variation, steers were ranked into high, medium, and low intake groups within each treatment, and intake restrictions for TRT1 and TRT2 were made with respect to each ranking. Steer BW were collected every 28 days for the duration of the experiment to determine animal performance via linear regression.

All steers were stepped up to a final finishing ration prior to the experiment and remained on this ration for the duration of the experiment (Table 1). The TRT1 and TRT2 intake restrictions occurred from day 0 through day 84 of the experiment. On day 84, these treatments were stepped up to *ad libitum* intake for the remainder of the experiment (day 134).

Enteric CH_4 and CO_2 production was determined utilizing two AHCS with a panel alleyway to ensure only one animal can access the systems at one time. Visits were set for a maximum of 6 drops per visit (approximately 36 g per drop) with 30-second intervals between each drop and a minimum of 4 hours between each visit to encourage animals to space visits throughout the day. This is of particular importance for meal-fed cattle where diurnal enteric CH_4 emission rates drastically change across the day (Gunter and

Beck, 2018). Only visits greater than 3 minutes in duration were used for subsequent analyses as recommended by Velazco et al. (2016). Enteric CH_4 results were analyzed as g CH_4/day, g of CH_4/lb of BW gain, and g of CH_4/lb of dry matter intake (DMI).

Results and Discussion

All results (Table 2) presented here encompass the entirety of the 134-day finishing period. There was no difference in initial BW between the three treatments, but there was a tendency for a linear reduction in BW at the end of the trial ($P = 0.08$). There was a reduction in DMI between the treatments ($P < 0.01$), but no difference in average daily gain (ADG) or gain:feed ($P \geq 0.15$). At the end of the intake restriction period on day 84, there was a tendency for a linear reduction in BW ($P = 0.10$) with TRT1 and TRT2 being similar at 1,200 and 1,204 lb compared to 1,265 lb for the CON. While the *ad libitum* intake period at the end of the finishing period did result in marginal increases in ADG for TRT1 and TRT2, the changes were not large enough to allow the steers to reach a similar end weight as CON steers.

For enteric CH_4 production, there was a quadratic effect of CH_4 on a g/day basis ($P = 0.02$). Emissions were lowest for TRT1 (114 g/day), intermediate for TRT2 (123 g/day), and highest for the *ad libitum* CON treatment (137 g/day). There was a reduction in DMI as well, when enteric CH_4 was expressed per lb of dry matter consumed, known as methane yield, there was a similar tendency for a quadratic response. This relationship did not continue when expressing emissions per lb of gain, referred to as emission intensity (EI). There was no difference between the three treatments for EI, with values ranging from 43.4 to 46.3 g CH_4/lb of gain.

Implications

These results indicate that limit feeding is a viable strategy to reduce enteric CH_4 emissions, as previous literature would indicate, due to the close association between intake over maintenance and enteric CH_4 production (Johnson and Johnson, 1995). Further, limit feeding did not negatively impact feed efficiency or animal performance, in part, due to the final *ad libitum* intake period for the restricted steers at the end of the study. However, this reduction in emissions will have to be balanced against the altered body composition and lighter final BW at finishing with limit fed steers. For the 17% reduction in absolute emissions to be worthwhile, economic incentives for producers would be needed to offset this less desirable endpoint.

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Table 1. Experimental diet

Ingredient	Dry matter (%)
Rolled corn	70.5
Sweet Bran, wet	15.1
Corn silage	6.1
Supplement	8.3
Nutrient dry matter (%) composition	
Dry matter, as fed (%)	76.3
Crude protein	11.3
Acid detergent fiber	7
Total digestible nutrients	15

Table 2. Impact of limit feeding on animal performance and enteric methane emissions

	Treatment[1]				*P*-value	
Item	CON	TRT1	TRT2	SEM[2]	Linear	Quadratic
Average daily gain, lb/day	3.13	2.74	2.77	0.08	0.12	0.31
Dry matter intake, lb/day	23.9	21.9	21.5	0.56	<0.01	0.21
Gain:feed	0.13	0.12	0.12	0.005	0.70	0.43
Enteric methane (g/day)	137	114	123	5.6	0.07	0.02
Methane yield[3]	5.7	5.2	5.7	0.2	0.87	0.06
Emission intensity[4]	45.2	43.4	46.34	3.0	0.79	0.52

[1]Treatments: CON = *ad libitum* intake; TRT1 = 96% *ad libitum* intake; TRT2 = 92% *ad libitum* intake.
[2]Standard error of the mean.
[3]Methane yield = g enteric CH_4/lb of dry matter consumed.
[4]Emission intensity = g enteric CH_4/lb of gain.