Impact of Biochar Supplementation in Finishing Diets on Greenhouse Gas Emissions

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Summary with Implications

A study was conducted to evaluate the impact of feeding biochar in a finishing diet on cattle performance, methane and carbon dioxide emissions, and carcass characteristics. Two treatments were evaluated, a high-concentrate control diet without biochar and a diet with biochar included at 1.0% of the diet dry matter, replacing high moisture corn in the diet. Pens of cattle were rotated through a two-sided emissions barn (2 pens evaluated simultaneously) to capture CH_4 and CO_2 production. There were no statistical differences in gas emissions for biochar supplemented steers compared to control. There was a 2.4% decrease in dry matter intake and 5.9% decrease in average daily gain for steers supplemented biochar, resulting in lighter and leaner carcasses for biochar fed steers.

Introduction

Methane (CH_4) emissions have been an environmental concern over the last few decades, and the beef industry has been challenged to lower/mitigate CH_4 emissions. One proposed method to reduce CH_4 production in cattle is by feeding biochar. Biochar is produced by burning organic matter at high temperatures in the absence of oxygen, resulting in a carbonized charcoal product. In cattle, CH_4 production is critical in ruminal fermentation, but does represent an energetic loss for the animal, estimated between 2 to 12% of total energy intake. There are several theories on mode of action when biochar is included in cattle diets. Biochar may adsorb CH_4, act as a hydrogen sink, or impact rumen microbial community, resulting in reduced CH_4 produced during rumination and eructation. A study conducted at UNL evaluated biochar supplemented to cattle at 0.8 and 3.0% of the diet and measured emissions utilizing headbox technology. This study reported a decrease in CH_4 emissions for cattle that were supplemented biochar at these concentrations in the diet (*2019 Nebraska Beef Cattle Report*, pp. 56–59). Biochar used in this experiment had a C content of 85%, bulk density of 5.5 lb/ft^3 and surface area of 323 m^2/g.

The objective of this study was to quantify the impact of biochar supplementation on cattle performance, CH_4 and CO_2 production, and carcass characteristics of finishing steers.

Table 1. Diet composition for steers fed a finishing diet with or without biochar inclusion (DM basis)

Ingredient, %	Control	Biochar
Wheat Straw	5	5
Sweet Bran[1]	35	35
High Moisture Corn	55	54
Supplement[2]	5	5
Biochar[3]	0	1

[1]Cargill Corn Milling, Blair, NE

[2]Formulated to provide 0.3% salt, 1.63% limestone, 0.10% tallow, beef trace mineral, vitamin A-D-E, Rumensin (Elanco Animal Health) targeted 30 g/ton, Optaflexx (Elanco Animal Health) targeted 300 mg/hd/d for last 28d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

[3]Biochar was added as an ingredient to the feed truck and replaced high moisture corn inclusion in the diet

Procedure

A 111-day feedlot finishing study was conducted at the University of Nebraska–Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. Yearling steers (n=128; initial BW=1058 lb) were assigned to two treatments (Table 1); a control finishing diet (no biochar inclusion) and finishing diet with 1.0% biochar inclusion which replaced 1% high moisture corn (HMC) in the ration. Diets were identical other than biochar inclusion, and contained wheat straw, HMC, and Sweet Bran (Cargill, Blair, NE).

Pens were assigned randomly to treatment (8 pens/treatment) and steers were stratified into 2 BW blocks (6 light reps and 2 heavy reps) and assigned randomly to pen (8 hd/pen). Before trial initiation, steers were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran offered at 2% of BW for 5 days. Steers were weighed in the morning of day 0 and 1 of trial and weights were averaged to establish initial BW. Steers were implanted with Revalor-200 (200 mg trenbolone acetate + 20 mg estradiol; Merck Animal Health, Summit, NJ) on day 1 of study.

Biochar was provided by High Plains Biochar (Laramie, WY), and was sourced from ponderosa pine wood waste. Dry matter of the biochar fluctuated with moisture in the air from 57% to 76% DM with an average of 70%. On a DM basis, carbon (C) content of the biochar was 82.8%, with a surface area of 426 m^2/g, bulk density of 6.73 lb/ft^3, and pH of 9.49. Biochar particle size ranged from < 0.5-mm to 8-mm, with approximately 66% of biochar sampled sizing <2-mm and 1% of biochar sampled >4-mm.

The UNL ENREC emission barn, equipped with a negative pressure system to monitor and record CH_4 and CO_2 production, was utilized for 8 consecutive weeks to monitor emissions from finishing steers. The emission barn has 2 isolated pens (no emission cross-over) and operates using two air sensors, the LI-COR 7500 and LI-COR 7700 (LI-COR, Lincoln, NE) to monitor CO_2 and CH_4, respectively. Eight pens of cattle, 4 control and 4 biochar, were selected randomly and rotated through the barn for two 5-d periods, with each treatment represented in the barn concurrently. Each week, steers entered the barn Wednesday morning, were removed Monday morning and returned back to their feedlot pen. Manure CO_2 and CH_4 emissions were calculated from the remainder of Monday. The barns were scraped clean each Tuesday to develop a baseline emission level post manure removal. An average CO_2 value of 17.45 g per steer and CH_4 value of 0.07 g per steer were subtracted from the daily emission total for CO_2 and CH_4 as contributions from manure.

Steers were harvested at a commercial abattoir (Greater Omaha, Omaha, NE) at study completion. Hot carcass weights were recorded on day of slaughter and USDA marbling scores, yield grade, and LM area were recorded after a 48-hr chill. Biochar is not currently approved by the FDA to be fed to cattle intended for human consumption. Prior to trial initiation, a food use authorization from the FDA was obtained for cattle utilized in this study to be harvested for human food use.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Performance data included BW block as a fixed effect and emissions data included barn as a fixed effect. Due to complications with the CO_2 analyzer, CO_2 emissions were averaged from one replication per treatment for each turn. In addition, one replication (week two of barn rotations) had unusable data for all emissions.

Table 2. Effect of biochar addition at 1.0% diet DM on performance and carcass characteristics of finishing steers

	Treatments			
	Control	Biochar	SEM	*P*-value
Performance				
Initial BW, lb	1057	1061	4.58	0.55
Final BW, lb	1471	1450	8.83	0.10
DMI, lb/d	29.5	28.8	0.14	<0.01
ADG, lb	3.73	3.51	0.069	0.02
Feed:Gain[1]	7.91	8.19	—	0.22
Carcass characteristics				
HCW, lb	927	914	5.6	0.10
LM area, in^2	14.8	14.7	0.14	0.93
Marbling	455	455	10.2	0.97
12th rib fat[2], in	0.61	0.57	0.018	0.12
Calculated yield grade	3.23	3.18	0.041	0.02

[1]Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[2]12th rib fat, in: calculated by back calculating from the USDA YG equation

Table 3. Effect of biochar addition at 1.0% diet DM on daily CO_2 and CH_4 emissions of finishing steers

	Treatments			
	Control	Biochar	SEM	*P*-value
DMI, lb/steer[1]	26.0	26.4	0.55	0.59
CH_4, g/steer	168.7	165.7	5.6	0.71
CH_4, g/lb of DMI	6.8	6.5	0.43	0.60
CO_2, g/steer	6282	6173	375	0.87
CO_2, g/lb of DMI	267	238	65	0.80

[1]Dry matter intake (DMI) used to determine emission quantities was averaged from the weekly intakes of each treatment during rotation through the emission barn

Results

Biochar supplemented steers had lower dry matter intake (DMI; $P < 0.01$; Table 2) and average daily gain (ADG; $P = 0.02$) and tended to have a lighter carcass adjusted final BW ($P = 0.10$) compared to the control. Feed conversion did not differ between the two treatments ($P = 0.22$; Table 2). Biochar supplemented steers tended to be lighter in hot carcass weight (HCW; $P = 0.10$) and USDA calculated yield grade was significantly lower ($P = 0.02$) for biochar fed steers compared to control due to lower ADG. Results from this study showed no difference in other USDA quality ($P = 0.97$) or yield grade parameters ($P \geq 0.12$) including LM area (in^2) and 12th rib fat (in). Emissions of CO_2 and CH_4 were not different between steers fed biochar and control treatments ($P \geq 0.60$; Table 3).

Conclusion

Pine-sourced biochar included at 1.0% of diet DM in finishing steers did not have a significant impact on CO_2 or CH_4 emissions. There was a numerical decrease in DMI and ADG for biochar fed steers, resulting in a lighter and leaner carcass. Type of diet, physical properties of the biochar, and inclusion percentage of biochar in the diet are all potentially influencing emission and performance differences across studies.

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