Ponderosa Pine Wood Biochar used as an Emissions Reduction Strategy in a Finishing Beef Cattle Diet

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Summary with Implications

A finishing feedlot experiment was conducted to evaluate the impact of feeding biochar on methane and carbon dioxide production, performance, and carcass characteristics in beef cattle. Two dietary treatments were evaluated; 0 or 1% biochar in a high concentrate diet comprised of dry-rolled corn, high moisture corn, Sweet Bran, and corn silage. Ponderosa pine wood biochar was added into the diet at 1% dry-matter displacing a 1% dry-matter blend of corn. Cattle were monitored using a calorimetry emissions barn to capture methane and carbon dioxide production. Emissions production, performance and carcass characteristics did not differ between cattle fed a control diet without biochar or cattle fed a diet containing biochar.

Introduction

The agricultural sector has been under scrutiny and challenged to reduce atmospheric gases such as methane (CH_4) and carbon dioxide (CO_2), specifically from enteric methane in cattle. Intake and diet quality are the main determinants of methane emissions. Enteric fermentation of feeds occurs within the rumen, naturally producing CH_4 through eructation as well as respired CO_2, but CH_4 losses are deemed unfavorable to the animal as this process comes at an energetic expense. Reduction strategies have been evaluated by using different dietary compositions and feed additive combinations. A product called biochar has been a proposed feed additive for its methane reduction potential properties. Biochar's mechanism is not fully understood, but theories suggest its large surface area and porous nature are favorable in promoting biofilm growth within the rumen resulting in increased feed degradation and reduced production of methane. The objective of this study was to evaluate the effect of biochar supplemented at 1% of diet dry matter (DM) on methane and carbon dioxide production, cattle performance, and carcass characteristics.

Table 1. Diet composition (% of DM) fed to finishing steers

Ingredient, %	Control	Biochar
Dry-rolled corn	20	19.5
High moisture corn	20	19.5
Sweet Bran	40	40
Corn silage	15	15
Biochar—wood[1]	-	1
Supplement	5	5
Fine ground corn	2.8825	2.8825
Limestone	1.60	1.60
Tallow	0.125	0.125
Salt	0.30	0.30
Trace mineral premix	0.05	0.05
Vitamin ADE	0.015	0.015
Rumensin-90[2]	0.0165	0.0165
Tylan-40[3]	0.011	0.011

[1]Displaced corn by 1% of diet DM
[2]Supplement formulated to provide 30 g/ton of Rumensin® (Elanco Animal Health, DM basis)
[3]Supplement formulated to provide 8.8 g/ton of Tylan® (Elanco Animal Health, DM basis)

Procedure

A 141 d experiment was conducted at the Eastern Nebraska Research, Extension and Education Center (ENREEC) near Mead, Nebraska. Prior to experiment initiation, cattle were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) on a DM basis at 2% of body weight (BW) for 5 d to equalize gut fill. One hundred twenty-eight steers were utilized in a randomized block design. To establish an average initial body weight (BW = 851 lb; SD ± 41 lb), steers were weighed on two consecutive days in the morning prior to feeding. Steers were blocked by BW into two weight blocks: light and heavy, stratified within BW, and assigned randomly to pens (n=16; 8 steers/pen). Pens were assigned randomly to one of two treatments (Control and Biochar; Table 1). Cattle were implanted with a Revalor-XS on d -1 (Merck Animal Heath, Summit, NJ). On d 141, cattle were harvested at Greater Omaha (Omaha, NE) recording hot carcass weight (HCW) and liver abscess scores on day of slaughter. Carcass-adjusted final BW was calculated using a common dressing percent of 63%. After a 48-hr chill, longissimus muscle (LM) area, 12th rib back fat, USDA marbling scores, and yield grade were measured and calculated. At the conclusion of the experiment, dietary energy content was calculated using cattle performance and net energy system equations.

A 24 d adaption period was utilized with corn silage inclusion decreasing in the diet and high moisture and dry rolled corn blend inclusion increasing while Sweet Bran and supplement remained constant.

Table 2. Biochar supplementation effect on performance and greenhouse gas emissions in finishing steers

	Treatment[1]			
	Control	Biochar	*SEM*	*P*- value
Performance				
Initial BW, lb	851	852	0.78	0.39
Final BW, lb[2]	1520	1511	9.36	0.47
Dry Matter Intake, lb/d	30.7	30.8	0.36	0.43
Average Daily Gain, lb	4.75	4.68	0.065	0.36
Feed:Gain[3]	6.43	6.55	—	0.21
NEm, Mcal/lb	0.83	0.82	0.006	0.29
NEg, Mcal/lb	0.54	0.53	0.006	0.29
Carcass Characteristics				
HCW, lb	958	952	5.90	0.47
LM area, in^2	14.6	14.6	0.223	0.84
12th rib fat thickness, in	0.69	0.66	0.026	0.45
Marbling score[4]	638	653	17.4	0.68
Daily Emissions, on a per animal basis				
Dry Matter Intake, lb/d[5]	27.2	27.4	1.02	0.91
CH_4, g/day	191.8	193.1	3.09	0.78
CH_4, g/lb of DMI	7.2	7.1	0.34	0.84
CO_2, g/day	4676	4213	461.7	0.50
CO_2, g/lb of DMI	174.3	154.5	20.55	0.52

[1] Treatments included cattle fed a control diet or 1% biochar replacing corn in the diet.

[2] Final BW calculated from Hot Carcass Weight (HCW) with a standard 63% dress.

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

[4] Marbling score 300 = slight, 400 = Small, 500 = Modest, 600 = Moderate

[5] Dry matter intake (DMI) used to calculate weekly average emissions during a 5-day collection period in the emission barn

The biochar was provided by Vital Ag (Bellwood, NE), sourced from ponderosa pine wood and made using the pyrolysis processing method. Monthly samples were taken, composited, and sent to Control Laboratories (Watsonville, CA) for physical and chemical analysis. The biochar maintained a consistent DM, ranging from 92% to 92.5%. Carbon composition was 74% of DM, a pH of 6.83, bulk density of 10.7 lb/ft^3, and a surface area of 180.5 m^2/g. Particle size distribution was categorized at <0.5mm (0.4%), 0.5–1mm (0.35%), 1–2 mm (4.2%), 2–4mm (23.25%), 4–8mm (47.85%) and 8–16mm (8.6%). Prior to experiment initiation, a food use authorization was granted which allowed for slaughter of these experimental cattle. Biochar fed to cattle intended for human consumption is not approved by the FDA.

Four replicates (4 control and 4 biochar pens paired together) were assigned randomly and monitored for 8 weeks using the pen scale emissions barn (*2019 Nebraska Beef Cattle Report*, pp. 60–62). Each replicate was monitored at two timepoints (once in each chamber), each lasting for 7 consecutive days. The barn uses a negative air pressure system equipped with LI-COR 7700 and LI-COR 7500 gas analyzers (LI-COR, Lincoln, NE) quantifying levels of CH_4 and CO_2. Each chamber is enclosed ensuring no air emissions crossover. Within each replicate, one control and one biochar treatment were simultaneously monitored during a seven-day period. Cattle entered the emissions barn on d 1 at 0700 h each Wednesday, remained in the designated chamber pen, exited on d 5 at 0700 h on Monday, and returned to their respective home pens. Days 1 to 5 were classified by time of feeding. One individual day was considered from time of feeding followed by the next days' time of feeding, approximately 24 hours. Day 6 consisted of manure contribution to CH_4 and CO_2 emissions, from the time cattle exited the barn to time of manure removal by a skid steer. Time after manure removal was assigned as d 7, until entry of the next cattle replicate and was used to correct for baseline measurements.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) as a randomized block design. Pen was the experimental unit and block was a fixed effect. Emissions data were analyzed as a repeated measure using a compound symmetry covariance structure and significance was declared at a $P < 0.05$.

Results

Cattle performance and carcass characteristics observed were not different between cattle fed the control or biochar finishing diet ($P \geq 0.21$; Table 2). On average cattle consumed 30.8 lb of feed each day ($P = 0.43$) while gaining 4.72 lb/d ($P = 0.36$) and a feed conversion of 6.49 ($P = 0.21$). The dietary energy concentration was not different between the control and biochar diet ($P = 0.29$). Cattle HCW was not affected by treatment, averaging 955 lb ($P = 0.47$).

The average methane captured for both treatments was 192.5 g/d, and 7.15 g/lb of DMI.

Carbon dioxide recorded averaged 4,444 g/d and 164 g/lb of DMI for both biochar and control fed cattle. Overall, emissions of CH_4 and CO_2 did not differ between cattle fed a diet with biochar or without biochar (Table 2; $P \geq 0.50$).

Conclusion

The addition of ponderosa pine wood biochar at 1% of diet DM did not reduce emissions of CH_4 or CO_2 from cattle. Performance and carcass characteristics were not different between cattle fed a high concentrate diet with or without biochar. Many factors are attributed to emissions reduction results such as cattle genetics, source and type of biochar, and diet quality. Research experiments using a low-quality forage growing diet (*2021 Nebraska Beef Cattle Report*, pp. 31–32), and high concentrate finishing diets (*2022 Nebraska Beef Cattle Report*, pp. 77–78; *2023 Nebraska Beef Cattle Report*, pp. 75-77) using the UNL pen-scale respiration calorimetry barn have demonstrated consistent results, in that feeding biochar does not reduce greenhouse gas emissions emitted by beef cattle.

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