Impact of Pistachio Shell Biochar in Finishing Beef Cattle Diets

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Summary with Implications

A 190-day finishing experiment was conducted to evaluate effects of feeding biochar on methane and carbon dioxide production, animal performance and carcass traits in beef steers. A high concentrate feedlot diet was used, and two dietary treatments were compared, 0 or 1% biochar as % of diet dry matter. Cattle were monitored using a calorimetry emissions barn to quantify production of methane and carbon dioxide. There were no differences in emissions, performance, or carcass characteristics for cattle fed the control diet or with biochar supplemented into the diet.

Introduction

Greenhouse gas emissions have been linked to global climate changes, specifically methane (CH_4) and carbon dioxide (CO_2). Within the agricultural industry, a primary goal has been to reduce methane emissions from beef cattle, as methane produced through enteric fermentation within the rumen is eructated into the atmosphere. This is a naturally occurring process but also an energetic expense to the animal.

Biochar is made from organic substances exposed to high temperatures producing a charcoal-like material and converting carbon into a more stable form. There are two different processing methods: gasification and pyrolysis. Gasification converts biomass primarily into syngas using high temperatures (600–900ºC) and oxidizing agents such as oxygen, steam, or CO_2. The pyrolysis method converts biomass at lower temperatures of 350–600ºC and does not include an oxidizing agent. While *in vitro* data have shown a decrease in methane with the addition of biochar, *in vivo* data have shown biochar fed at 0.8 to 1% of the diet did not reduce emissions using headbox calorimetry (*2019 Nebraska Beef Cattle Report*, pp. 56–59) or in a production setting using pen calorimetry chambers and a variety of beef cattle diets (*2021 Nebraska Beef Cattle Report*, pp 31–32; *2022 Nebraska Beef Cattle Report*, pp. 77–78). The objective of this study was to evaluate the effect of biochar made by gasification and supplemented at 1% of diet dry matter (DM) on methane (CH_4) and carbon dioxide (CO_2) production, cattle performance, and carcass characteristics.

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

Ingredient, %	Control	Biochar
Dry-rolled corn	35	34.5
High moisture corn	35	34.5
Modified distillers grains plus solubles	20	20
Corn residue	5	5
Biochar—pistachio shells[1]	-	1
Supplement	5	5
Fine ground corn	2.3125	2.3125
Limestone	1.67	1.67
Tallow	0.125	0.125
Urea	0.50	0.50
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 finishing cattle experiment was conducted at the Eastern Nebraska Research, Extension and Education Center near Mead, NE. One hundred twenty-eight steers (initial BW = 725 lb; SD = 41 lb) were utilized in a randomized block design. 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 gastrointestinal fill. Weights were taken on two consecutive days in the morning prior to feeding to establish an average initial body weight (BW). 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-IS on d 1 and reimplanted with a Revalor-200 on d 79 (Merck Animal Heath, Summit, NJ). On d 190, cattle were harvested at Greater Omaha (Omaha, NE) recording liver abscesses and hot carcass weight (HCW) 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 and USDA marbling scores were recorded and yield grade were calculated using an assumed 2% KPH (kidney, pelvic and heart fat). At the conclusion of the experiment, dietary energy content was calculated using cattle performance and net energy system equations.

A 24-day step-up period was used to adapt cattle to the finishing diet. The adaption diet included 35% haylage and 10% corn stalks which was displaced with an equal blend of dry-rolled corn (DRC) and high moisture corn (HMC), increasing from 30% to 70% of the diet DM. The final base diet (CON) consisted of 35% DRC, 35% HMC, 5% corn stalks, 20% modified distillers grains plus solubles (MDGS), and 5% supplement. Biochar was incorporated into the diet on d 1 at 1.0% of diet DM and displaced both DRC and HMC at 0.5% each, with all other diet ingredient inclusions remaining constant.

The biochar was sourced from VGrid Energy Systems, Inc. (San Pablo, CA) and was made from pistachio shells using the processing method of gasification. Monthly samples were taken and sent to Control Laboratories (Watsonville, CA) for physical and chemical analysis. The biochar maintained a consistent DM, ranging from 90.4% to 92.5% (average of 91.6%). Carbon composition was 85% of DM, with a pH of 9.03, bulk density of 23.8 lb/ft^3, and a surface area of 217 m^2/g. Particle size distribution was categorized at <0.5mm (62.8%), 0.5–1mm (35.7%) and 1–2 mm (1.5%). Prior to trial initiation, VGrid Energy Systems established GRAS (Generally Recognized As Safe) status with Nebraska Department of Agriculture, as biochar is not approved by the FDA to be fed to cattle that will enter the food supply chain.

Four replicates (4 control and 4 biochar pens paired together) were assigned randomly and monitored for 16 consecutive weeks using the pen scale emissions barn (*2019 Nebraska Beef Cattle Report*, pp 60–62). Each replicate was measured 4 times in the barn (twice in each chamber). 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 captured manure contribution 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 included as a fixed effect. Emissions data were analyzed as a repeated measure using an unstructured covariance structure and significance was declared at a $P < 0.05$.

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	725	724	0.97	0.52
Final BW, lb[2]	1506	1519	13.7	0.36
Dry Matter Intake, lb/d	25.1	25.3	0.28	0.61
Average Daily Gain, lb	4.11	4.18	0.049	0.31
Feed:Gain[3]	6.32	6.26	—	0.46
NEm, Mcal/lb	0.87	0.87	0.006	0.78
NEg, Mcal/lb	0.57	0.58	0.005	0.78
Carcass Characteristics				
HCW, lb	949	957	6.03	0.36
LM area, in^2	14.8	14.8	0.199	0.90
12th rib fat thickness, in	0.66	0.60	0.032	0.20
Marbling score[4]	527	514	11.8	0.45
Daily Emissions, on a per animal basis				
Dry Matter Intake, lb/d[5]	27.6	27.8	1.02	0.81
CH_4, g/day	141.4	144.2	5.80	0.76
CH_4, g/lb of DMI	5.9	5.9	0.38	0.88
CO_2, g/day	5245	5210	314.6	0.94
CO_2, g/lb of DMI	219.6	218.2	6.69	0.88

[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

Results

Cattle performance and carcass characteristics were not statistically different between treatments ($P \geq 0.20$; Table 2). Across both treatments cattle consumed 25.2 lb (DM basis) of feed each day ($P = 0.61$) while gaining 4.15 lb/d ($P = 0.31$). Cattle performed with an average feed conversion of 6.29 ($P = 0.46$). Dietary energy concentration was not different between treatments ($P = 0.78$). Hot carcass weight of cattle was not impacted by treatment, averaging 953 lb ($P = 0.36$).

For both treatments, the average methane production was 142.8 g/d and 5.9 g of CH_4/lb of DMI. Carbon dioxide recorded averaged 5,228 g/d and 218.9 g/lb of DMI. Overall, emissions of CH_4 and CO_2 did not differ among cattle fed a diet with or without biochar (Table 2; $P \geq 0.76$).

Conclusion

Biochar sourced from pistachio shells included at 1% of diet DM did not show any advantages for reducing CH_4 and CO_2 emissions, but did not adversely impact cattle health, animal performance or carcass traits. Previous *in vivo* biochar research has shown inconsistent results on reducing emission levels, as there are many factors of biochar to be considered: processing method, source, physical and chemical composition. After multiple studies conducted utilizing the two-pen scale emission barn at UNL, no specific diet or type of biochar combination has yet proven to reduce CH_4 or CO_2 from finishing beef cattle.

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