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Biochar Supplementation in Growing and Finishing Diets

Tommy M. Winders

Collin B. Freeman

Brittney A. Mark Mark

Melissa L. Jolly-Breithaupt

Hannah C. Hamilton
University of Nebraska - Lincoln, hhamilton6@unl.edu

See next page for additional authors

Authors
Tommy M. Winders, Collin B. Freeman, Brittney A. Mark Mark, Melissa L. Jolly-Breithaupt, Hannah C. Hamilton, Jim C. MacDonald, Galen E. Erickson, and Andrea K. Watson

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Summary with Implications

Two metabolism studies were conducted to evaluate the effects of biochar (0, 0.8, or 3% of diet dry matter) on digestibility and methane production in growing and finishing diets. Intake was not affected by biochar inclusion in the growing diet and increased with 0.8% biochar inclusion in the finishing study. Digestibility tended to increase quadratically with biochar inclusion in the growing study while digestibility tended to linearly decrease with biochar inclusion in the finishing study. Methane production (g/d) decreased 10.7% in the growing study and 9.9% in the finishing study with 0.8% biochar compared to no biochar. Methane production was reduced 10.6% and 18.4% in the growing and finishing studies, respectively, when measured as g/lb of intake. Although biochar is not FDA approved for animal feeding, the initial research shows potential as a methane mitigation strategy in both growing and finishing diets.

Introduction

Energy lost as methane by ruminants can range from 2–12% of gross energy intake (GEI), but is variable depending on multiple things, with diet composition being one factor. Diet composition can be used to manipulate the rumen environment and is a methane mitigation strategy. Biochar is a feed product with potential as a methane inhibitor. Biochar is produced by burning organic matter (OM; typically plant material) at very high temperatures in the absence of oxygen. Although a mode of action is not fully understood, it has been suggested that it adsorbs gas in the rumen resulting in reduced methane eructation. Other theories are that the porous nature of biochar will increase the amount of inert surface area in the rumen, allowing for improved habitat for microbes to reside. This improved habitat may increase microbial growth, allow feeds to be digested more completely, and bring methanogens and methanotrophs together, leading to more complete oxidation of feeds and less methane production.

Table 1. Composition of diet (DM basis) fed to cattle (Growing trial)

	Biochar, % Inclusion		
Ingredient, % of diet DM	0	0.8	3
Brome hay	21	21	21
Wheat straw	20	20	20
Corn silage	30	30	30
Wet distillers grains plus solubles	22	22	22
Supplement[1]			
Fine ground corn	4.630	3.830	1.630
Biochar	-	0.800	3.000
Limestone	1.320	1.320	1.320
Tallow	0.175	0.175	0.175
Urea	0.500	0.500	0.500
Salt	0.300	0.300	0.300
Beef Trace Mineral[2]	0.050	0.050	0.050
Vitamin A-D-E[3]	0.015	0.015	0.015

[1]Supplement fed at 7% of diet DM
[2]Premix contained 10% Mg, 6% Zn, 2.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co
[3]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g
[4]Formulated to supply Rumensin-90 (Elanco Animal Health; Greenfield, IN) at 18 g/ton

Procedure

Growing Experiment

Six crossbred steers (initial BW 1166 lb; standard deviation = 35 lb) were used in a 6-period crossover design. Steers were blocked by body weight (BW) and assigned randomly within block to 1 of 3 treatments. Periods ranged from 14–24 days with 2 consecutive, 23-h periods in the headbox calorimeter. The availability of the calorimeters dictated period length. Diets fed were identical between treatments other than inclusion of biochar (0, 0.8, or 3% of diet dry matter; DM), which displaced fine-ground corn in the supplement (Table 1). The biochar was derived from pine trees and had a composition of 85% carbon, 0.7% nitrogen, and was 94% OM on a DM basis. Diets consisted of 30% corn silage, 21% brome hay, 20% wheat straw, 22% wet distillers grains plus solubles (WDGS), and 7% supplement (DM basis). Urea was included in the supplement of all diets at 0.5% of diet DM and treatments provided 200 mg/animal daily of monensin (Rumensin, Elanco Animal Health, Greenfield, IN).

Diets were fed *ad libitum* twice daily with 50% of daily feed offered at each feeding. Each period consisted of adaptation to the treatments (minimum of 8 d), fecal grab sampling 4 times/d on 4 days leading up to headbox collections, and headbox collections for the final 2 d of the period. Feed and fecal samples were ground through a

Table 2. Composition of diet (DM basis) fed to cattle (Finishing trial)

	Biochar, % Inclusion		
Ingredient, % of diet DM	0	0.8	3
Dry-rolled Corn	53	53	53
Corn silage	15	15	15
Wet distillers grains plus solubles	25	25	25
Supplement[1]			
Fine ground corn	4.630	3.830	1.630
Biochar	-	0.800	3.000
Limestone	1.320	1.320	1.320
Tallow	0.175	0.175	0.175
Urea	0.500	0.500	0.500
Salt	0.300	0.300	0.300
Beef Trace Mineral[2]	0.050	0.050	0.050
Vitamin A-D-E[3]	0.015	0.015	0.015
Rumensin-90[4]	0.010	0.010	0.010

[1]Supplement fed at 7% of diet DM

[2]Premix contained 10% Mg, 6% Zn, 2.5% Mn, 0.5% Cu, 0.3% I, and 0.05% Co

[3]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of vitamin E per g

[4]Formulated to supply Rumensin-90 (Elanco Animal Health; Greenfield, IN) at 18 g/ton

Table 3. Effect of biochar inclusion on intake and total tract digestibility (Growing trial)

	0	0.8	3	SEM	Lin[1]	Quad[2]
DM						
Intake, lb/d	17.7	17.4	17.3	0.46	0.43	0.64
Digestibility, %	55.7	57.6	54.7	1.12	0.25	0.11
OM						
Intake, lb/d	16.0	15.8	15.7	0.42	0.52	0.74
Digestibility, %	58.6[ab]	60.6[a]	57.7[b]	1.16	0.31	0.10
NDF						
Intake, lb/d	9.35	9.24	9.44	0.24	0.62	0.57
Digestibility, %	50.5[ab]	52.6[a]	48.2[b]	1.55	0.08	0.10
ADF						
Intake, lb/d	6.24	6.22	6.46	0.18	0.13	0.53
Digestibility, %	46.7	48.1	45.0	1.50	0.29	0.35
Energy						
GE intake, Mcal/d	35.3	34.8	34.8	0.93	0.62	0.68
DE intake, Mcal/d	20.5	21.0	20.0	0.51	0.27	0.30

[1]Linear effect on response variables

[2]Quadratic effect on response variables

[a, b] Means within a row with different superscripts are different ($P < 0.10$)

1-mm screen and analyzed for DM, OM, acid detergent fiber (ADF), neutral detergent fiber (NDF), GE and digestible energy (DE). Bomb calorimetry was done to obtain energy values. Acid insoluble ash (AIA) was used as an internal marker and analysis was done on the base diet fed, feed refusals, and fecals to determine digestibility DMD.

Finishing Experiment

The same 6 steers were utilized in a 3-period crossover design. Steers remained in the same BW block and were assigned randomly to 1 of 3 treatments. Similar to the growing experiment, diets fed were identical between treatments other than inclusion of biochar (0, 0.8, or 3% of diet DM), which displaced fine-ground corn in the supplement (Table 2). Diets consisted of 53% dry rolled corn, 15% corn silage, 25% WDGS, and 7% supplement, on a DM basis. Periods were 14 days in length with 2 consecutive 23-hr headbox collections over the last 2 days of each period. Fecal output was estimated by dosing 10 g/d of titanium dioxide in the feed and was used to calculate diet digestibility. All other procedures were the same as described for the growing experiment. At the conclusion of the trial, cattle were euthanized under veterinary supervision and composted because biochar is not an FDA approved feed additive.

Gas emissions

In both experiments, methane emissions were measured through indirect calorimetry using headboxes built at the University of Nebraska–Lincoln. A training period was done before the experiment for steers to become acclimated to the headboxes. One steer was removed from the growing experiment after period two because of a lack of dry matter intake (DMI) while in the headbox, but was re-trained and used during the finishing experiment. Gas samples were collected in foil bags that continuously and evenly filled throughout the 23 h collection period. Gas measurements collected over the 2 d were averaged to obtain 1 value per period for each steer. A 5 d DMI average leading up to the 2 d headbox period was used to report gas emissions on a grams per lb of DMI basis.

Digestibility and gas emissions were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Steer within period was the experimental unit and steer was included in the random statement. Probabilities were considered significant at $P \leq 0.10$ and tendencies are discussed at $P \leq 0.15$.

Results

Growing Experiment

DIGESTIBILITY AND ENERGY

All intake, fecal output and digestibility data are reported in Table 3. Dry matter intake (lb/d) did not differ between treatments ($P \geq 0.43$; Table 3), but did increase between periods as a result of the cattle growing, and therefore eating more. There were no differences between treatments in intake of DM, OM, NDF, or ADF ($P \geq 0.13$). Dry matter digestibility and OM digestibility (OMD) were not different ($P \geq 0.15$) from the control diet at either biochar inclusion. A linear ($P = 0.08$) decrease was observed for NDF digestibility (NDFD) with 3% inclusion of biochar having the lowest digestibility. Gross energy intake (GEI; Mcal/d) and digestible energy intake (DEI; Mcal/d) did not differ between treatments ($P \geq 0.27$).

Methane Production

Reported DMI used for gas emission calculations was a 5 d average prior to cattle entering the headboxes, and was not different between treatments ($P \geq 0.68$; Table 4). Methane production (g/d) tended to decrease quadratically ($P = 0.14$) with the 0.8% biochar treatment reducing methane compared to the 0% treatment. Numerically, the 0.8% biochar treatment reduced methane (g/d) by 11% compared to the control treatment without biochar. Methane production calculated as g/lb of DMI or g/Mcal of GEI was not different between treatments ($P \geq 0.17$). Methane produced per Mcal of DEI was lowest for 0.8% biochar and greatest for the 0% treatment, resulting in a quadratic response ($P = 0.05$).

When combining the two treatments that contained biochar (0.8 and 3%) and comparing to the 0% biochar treatment, methane production (g/d, g/lb DMI, and g/Mcal GEI) tended ($P \leq 0.13$) to be lower for the biochar cattle relative to the control cattle. Methane produced per Mcal of DEI was reduced ($P = 0.07$) for the biochar cattle.

Finishing Experiment

Digestibility

Intake of DM, OM, NDF, and ADF all increased quadratically ($P < 0.01$) as biochar inclusion in the diet increased (Table 5). Dry matter digestibility tended to decrease linearly ($P = 0.11$) as biochar inclusion increased, while OMD and ADFD did decrease linearly ($P \leq 0.10$) as biochar inclusion increased.

Table 4. Effect of increasing inclusion of biochar on methane emissions from steers (Growing trial)

	Biochar Inclusion, % DM				*3 Types P-value*		*Bio vs No Bio*[3]
	0	0.8	3	SEM	Lin[1]	Quad[2]	*P*-value
DMI, lb/d	17.4	17.4	17.2	0.4	0.68	0.90	0.70
GE intake, Mcal/d	34.9	34.7	34.8	0.9	0.99	0.85	0.88
DE intake, Mcal/d	20.6	21.1	20.3	0.5	0.50	0.32	0.82
Methane							
g/d	108.8	97.2	100.7	5.1	0.42	0.14	0.11
g/lb DMI	6.25	5.59	5.85	0.30	0.43	0.18	0.13
g/Mcal GE intake	3.10	2.80	2.86	0.13	0.37	0.17	0.11
g/Mcal DE intake	5.27[a]	4.62[b]	4.92[ab]	0.21	0.51	0.05	0.07

[1]Linear effect on response variables
[2]Quadratic effect on response variables
[3]Biochar vs. No biochar inclusion
[a, b]Means within a row with different superscripts are different ($P < 0.10$)

Table 5. Effect of biochar inclusion on intake and total tract digestibility (Finishing trial)

	0	0.8	3	SEM	Lin[1]	Quad[2]
DM						
Intake, lb/d	26.4[a]	28.5[b]	26.8[a]	1.2	0.48	< 0.01
Digestibility, %	71.5	70.0	68.2	1.8	0.12	0.70
OM						
Intake, lb/d	22.5[a]	24.4[b]	22.8[a]	1.0	0.33	< 0.01
Digestibility, %	72.3[a]	70.4[ab]	68.7[b]	1.7	0.10	0.45
NDF						
Intake, lb/d	6.62[a]	7.40[b]	7.47[b]	0.33	< 0.01	< 0.01
Digestibility, %	56.6	54.1	53.4	3.8	0.22	0.43
ADF						
Intake, lb/d	2.82[a]	3.18[b]	3.38[c]	0.13	< 0.01	< 0.01
Digestibility, %	52.4[a]	50.1[a]	41.3[b]	3.8	< 0.01	0.75

[1]Linear effect on response variables
[2]Quadratic effect on response variables
[a,b,c]Means within a row with different superscripts are different ($P < 0.10$)

Table 6. Effect of increasing inclusion of biochar on methane emissions from steers (Finishing trial)

	Biochar Inclusion, % DM				*3 Types P-value*		*Bio vs No Bio*[3]
	0	0.8	3	SEM	Lin[1]	Quad[2]	*P*-value
DMI, lb/d	24.8[a]	28.0[b]	26.3[b]	1.1	0.52	0.01	0.04
Methane							
g/d	141	127	122	19	0.39	0.62	0.32
g/lb DMI	5.65	4.61	4.83	0.66	0.48	0.85	0.22

[1]Linear effect on response variables
[2]Quadratic effect on response variables
[3]Biochar vs. No biochar inclusion
[a, b]Means within a row with different superscripts are different ($P < 0.10$)

Methane Production

Intake used for gas emission calculations increased quadratically ($P = 0.01$) as biochar inclusion increased. When biochar treatments were combined, biochar cattle had greater DMI ($P = 0.04$) than the control. Methane production (g/d and g/lb DMI) was not different between treatments ($P \geq 0.22$) when analyzed as three inclusion levels or as biochar inclusion vs. no biochar inclusion (Table 6). However, methane production (g/d) numerically decreased 9.9% and methane production (g/lb DMI) decreased 18.4% for the 0.8% biochar treatment relative to no biochar. Only 3 periods of data were collected in the finishing experiment (6 periods in the growing experiment) due to cattle becoming too large for the headboxes, which limited statistical power.

While not always statistically significant, there were consistent numerical decreases in methane production with 0.8% biochar inclusion in the diet compared to no biochar. Intake was not hindered with biochar inclusion, and actually increased in the finishing experiment. Feeding 0.8% biochar appears to be sufficient and no further benefits were observed from increasing inclusion to 3% of diet DM. The effects of biochar in the rumen show promise, but are not fully understood and performance data (ADG, efficiency, carcass data) are needed to determine if it is a feasible methane mitigation tool.

Tommy M. Winders, graduate student

Collin B. Freeman, undergraduate student

Brittney A. Mark, undergraduate student

Melissa L. Jolly-Breithaupt, research technician

Hannah C. Wilson, research technician

Jim C. MacDonald, associate professor

Galen E. Erickson, professor

Andrea K. Watson, research assistant professor, University of Nebraska–Lincoln, Department of Animal Science, Lincoln, Neb.