Effect of Biochar as a Feedlot Pen Surface Amendment on Manure Nutrient Capture

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Summary with Implications

Two mass balance experiments were conducted during winter and summer seasons to evaluate the effect of spreading biochar on the feedlot pen surface on manure nutrient retention. The winter experiment (Dec to June) evaluated three treatments including biochar spread to pen surface (approximately 54 lb of biochar per steer), hydrated lime spread to pen surface (cooperation with UNL Environmental Engineering; approximately 68 lb per steer) and negative control (no treatment applied). The summer experiment (June to Nov) evaluated biochar treatment (approximately 68 lb of biochar per steer) against negative control. Biochar utilized in winter and summer was unprocessed and sourced from Eastern red cedar. Biochar addition to the feedlot pen surface increased N concentration in manure but did not translate into increased lb of N or P removed from feedlot pens (mass balance) for both experiments. There was a significant improvement in steer average daily gain for biochar addition in the summer, with no impact on steer performance or carcass characteristics for winter.

Introduction

Improving manure nutrient capture of nitrogen (N) and phosphorus (P) is beneficial for the environment, with less nitrogen lost to the atmosphere via volatilization, and has the potential to improve the economic value of manure as a fertilizer. One proposed method of improving manure nutrient capture of N and P is applying biochar to the feedlot pen surface. Biochar can be produced from forest industry by-products (wood trimmings, etc.) and has been used as a soil amendment and manure treatment. The utilization of biochar as a soil amendment has shown improved plant and soil health, reduced nutrient losses via leaching and volatilization, improved soil structure (by reducing erosion), and sequestration of carbon.

The objective of this study was to evaluate the effects of applying biochar to the feedlot pen surface during two seasonal feeding periods on manure N, P, and organic matter (OM). The application of hydrated lime (calcium hydroxide) to the feedlot pen surface was in cooperation with UNL Environmental Engineering to determine the impact of lime on microbial activity on the pen surface. The alkaline stabilization properties of lime are hypothesized to reduce antimicrobial resistant bacteria in cattle manure (*2022 Nebraska Beef Cattle Report*, pp. 91–94).

Table 1. Diet composition[1] for steers in WINTER mass balance

Ingredient	Diet Inclusion, % DM
High moisture corn	51
Sweet Bran[2]	20
Corn Silage	15
Modified distillers grains	10
Supplement[3]	4

[1]Mean dietary crude protein 13.7% and dietary P 0.45%

[2]Cargill Corn Milling, Blair, NE

[3]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 28 d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

Procedure

Cattle Performance

The WINTER (Dec to June) and SUMMER (June to Nov) mass balance experiments were conducted at the University of Nebraska–Lincoln Eastern Nebraska Research, Extension and Education Center (ENREEC) near Mead, NE.

In WINTER, crossbred calves (n = 150; initial BW = 604 lb) were assigned to three treatments; negative control, biochar application to pen surface, and lime application to pen surface. Unprocessed biochar made from Eastern red cedar trees was applied to the pen surface in equal volumes (approximately 270 lb dry matter; DM; per pen) at trial initiation in December and again in February. Lime treatment was applied to pen surface (approximately 680 lb DM per pen) one day prior to shipping cattle for harvest Pens were assigned randomly to treatment (5 pens/treatment) and steers were assigned randomly to pen (10 hd/pen). Steers were on feed for 186 d and the finishing diet contained high moisture corn (HMC), Sweet Bran (Cargill Corn Milling, Blair, NE), corn silage, and modified distillers grains (Table 1).

In SUMMER, crossbred yearlings (n = 80; initial BW = 747 lb) were assigned to two treatments; negative control and biochar application to pen surface. Unprocessed biochar was applied to the pen surface in equal volumes (approximately 270 lb DM per pen) at trial initiation in June and again in August. Pens were assigned to the same treatment (5 pens/treatment) as the WINTER phase and steers were assigned randomly to pen (8 hd/pen). Steers were on feed for 153 d and the finishing diet contained HMC, Sweet Bran, and cornstalks (Table 2).

Table 2. Diet composition[1] for steers in SUMMER mass balance

Ingredient	Diet Inclusion, % DM
High moisture corn	51
Sweet Bran[2]	40
Cornstalks	5
Supplement[3]	4

[1]Mean dietary crude protein 14.5% and dietary P 0.53%

[2]Cargill Corn Milling, Blair, NE

[3]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 28 d, Tylan (Elanco Animal Health) targeted 90 mg/hd/d as % of diet DM, with fine ground corn as the carrier

Table 3. Performance and carcass characteristics for steers fed the same diet with different pen amendments in WINTER phase

	Treatments[1]				
	Control	Biochar	Lime	SEM	*P*-value
Performance					
Initial BW, lb	604	604	604	2.8	0.95
Final BW, lb	1363	1372	1384	12.4	0.50
DMI, lb/d	22.1	22.2	22.6	0.08	0.10
ADG, lb	4.09	4.13	4.19	0.064	0.50
Feed:Gain[2]	5.41	5.39	5.39	—	0.98
Carcass characteristics					
HCW, lb	859	864	871	7.8	0.50
LM area, in^2	13.4	13.6	13.6	0.20	0.76
Marbling	472	463	476	13.71	0.79
12th rib fat[3], in	0.57	0.55	0.56	0.020	0.79
Calculated yield grade	3.43	3.38	3.40	0.050	0.78

[1]Control = no treatment applied; Biochar = red cedar biochar applied in Dec and Feb at 270 lb per pen for each application; Lime = applied 1 d prior to cattle harvest approximately 680 lb per pen

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

[3]12th rib fat calculated from the USDA YG equation

Biochar was provided by Sawle Mill (Springview, NE), and was sourced from Eastern red cedar trees. Dry matter of the biochar fluctuated with moisture in the air from 85% to 95% DM with an average of 90%. On a DM basis, carbon (C) content of the biochar was 80.3%, with a surface area of 233 m^2/g, bulk density of 9.7 lb/ft^3, and pH of 6.3. Biochar particle size ranged from 0.5-mm to 50-mm, with approximately 70% of biochar sampled sizing >8-mm.

Prior to WINTER and SUMMER 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-IS (80 mg trenbolone acetate + 16 mg estradiol; Merck Animal Health, Summit, NJ) on d 1 of study and reimplanted with Revalor-200 (200 mg trenbolone acetate + 20 mg estradiol; Merck Animal Health, Summit, NJ) on d 76 and d 68 for WINTER and SUMMER, respectively.

Steers were harvested at a commercial abattoir (Greater Omaha, Omaha, NE) at WINTER and SUMMER completion. Hot carcass weights (HCW) were recorded on day of slaughter and USDA marbling scores, yield grade, and LM area were recorded after a 48- and 72-hr chill for WINTER and SUMMER, respectively. Performance traits including final body weight (BW), average daily gain (ADG), and feed:gain (F:G) were calculated based on HCW adjusted to a common dressing percentage of 63.

Nutrient Mass Balance

Nutrient mass balance experiments were conducted using open dirt feedlot pens. Prior to cattle entering pens, 12 soil core samples (6-inch depth) were taken from each pen for both experiments. After cattle were removed from pens on day 186 (WINTER) and 153 (SUMMER), pen surface was cleaned with a box scraper, and a skid steer scraped the cement apron and piled manure. The manure pile was sampled (n = 30) for moisture and nutrient analysis as manure was loaded out from the pen. Manure trucks were weighed to determine weight of manure removed from each individual pen. Manure samples (n = 10 per pen; analyzed in duplicate) were oven dried over 48-hr to determine DM removal from each pen. Nutrient analysis was completed by Ward Laboratories (Kearney, NE) on manure samples (n = 20 per pen) after freeze drying. Following manure removal from pen, an additional 12 soil cores per pen were sampled to determine pen cleaning equivalence.

Nutrient intake was determined by monthly feed ingredient composites and feed refusals on a pen basis. The N and P retained by the animal were calculated utilizing energy, protein, and P retention equations. Nutrient excretion was then calculated by subtracting nutrient retention from nutrient intake. Runoff was not measured in this experiment, and generally accounts for 3–5% of total nutrient lost from an open dirt lot. Total nutrient loss (lb/steer) was calculated by subtracting manure nutrients (corrected for soil cores) from excreted nutrients. Cattle performance and nutrient mass balance data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit.

Table 4. Performance and carcass characteristics for steers fed the same diet in SUMMER phase

	Treatments[1]			
	Control	Biochar	SEM	*P*-value
Performance				
Initial BW, lb	747	747	2.39	0.92
Final BW, lb	1466	1503	13.20	0.05
DMI, lb/d	26.7	26.8	0.099	0.48
ADG, lb	4.70	4.94	0.086	0.05
Feed:Gain[2]	5.69	5.43	—	0.08
Carcass characteristics				
HCW, lb	924	947	8.3	0.05
LM area, in^2	14.4	14.4	0.18	0.89
Marbling	492	499	15.1	0.76
12th rib fat[3], in	0.59	0.59	0.026	0.98
Calculated yield grade	3.48	3.48	0.065	0.98

[1]Control = no treatment applied; Biochar = red cedar biochar applied in June and August at 270 lb per pen for each application

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

[3]12th rib fat calculated from the USDA YG equation

Results

Cattle Performance

There were no significant differences in dry matter intake (DMI; *P* = 0.10), ADG or F:G (*P* ≥ 0.50) due to pen treatment in WINTER (Table 3). Carcass characteristics were not impacted by pen treatments for cattle in WINTER (*P* ≥ 0.50). There was a significant increase in carcass-adjusted final BW (*P* = 0.05) and ADG (*P* = 0.05) for steers on biochar amended treatment in SUMMER (Table 4) compared to control, and no difference between treatments for DMI (*P* = 0.48). This improvement in gain tended to improve feed conversion (*P* = 0.08) for steers in biochar treated pens compared to control and resulted in significantly heavier HCW (*P* = 0.05) for biochar treatment. Results from SUMMER showed no difference in other USDA quality or yield grade parameters (*P* ≥ 0.76).

The significant increase in ADG and final BW for SUMMER steers on biochar treatment may have been influenced by the moisture content of the pen surface (*2021 Nebraska Beef Cattle Report*, pp. 95–104). The biological and chemical properties of wood-sourced biochar may absorb water and reduce moisture content on the pen surface reducing the impacts of mud; however, pen surface moisture across time was not measured in this experiment. More biochar per animal was added to the pen surface for SUMMER experiment and the SUMMER feeding period had greater precipitation compared to WINTER.

Nutrient Mass Balance

In the WINTER experiment (Table 5), N intake, retention, and excretion were similar between treatments (*P* ≥ 0.42). Manure concentration of N tended to differ between treatments (*P* = 0.07), with biochar treatment having the greatest manure N as a percent of manure DM. In WINTER, P intake, retention, and excretion were all similar between treatments (*P* ≥ 0.38) and there was no difference between treatments in concentration of manure P (*P* = 0.23) as a percent of manure DM. Manure nutrient amounts (with correction for soil) were numerically greatest in lime treatment and lowest in biochar treatment for N (*P* = 0.15) and P (*P* = 0.75). Manure nutrient losses were similar for all treatments and averaged 54% loss of N (*P* = 0.68) and 0.43% loss of P (*P* = 0.87). The DM removed from the pen surface in WINTER was numerically lowest for biochar treatment (*P* = 0.17). Oven dried manure samples averaged 89, 88, and 90% DM content for control, biochar, and lime, respectively.

In the SUMMER experiment (Table 6), N intake and excretion were similar between treatments (*P* ≥ 0.35) and steers on biochar treatment had significantly greater N retention compared to the control (*P* = 0.04). The intake and excretion of P was similar between treatments (*P* ≥ 0.35), and P retention was significantly greater for biochar treatment compared to control (*P* = 0.03). Steers fed in biochar-treated pens had significantly higher ADG (*P* = 0.05), and final BW (*P* = 0.05) compared to control, resulting in greater N and P retention. The manure DM removed from the pen surface in SUMMER tended to be greater for control treatment (*P* = 0.08). Manure N as a percent of manure DM tended to be greatest for biochar treatment (*P* = 0.07) with no difference in manure P as a percent of manure DM (*P* = 0.23). Manure nutrient losses were similar for biochar and control with 71% of N (58 lb/steer; *P* ≥ 0.78) and 10% of P (10 lb/steer; *P* ≥ 0.88) lost during the SUMMER experiment. Oven dried manure samples averaged 55 and 56% DM content for control and biochar, respectively.

Conclusion

These data suggest that the addition of unprocessed red cedar biochar to the feedlot pen surface (54 to 68 lb per steer) did not improve manure nutrients and did not decrease N losses. Biochar addition to the feedlot pen surface did improve growth performance of steers in the SUMMER phase, although no differences were found in growth performance for the WINTER phase.

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Table 5. Effect of biochar and lime pen amendments on nitrogen (N), phosphorus (P) and organic matter (OM) during WINTER[1]

	Treatments[2]				
	Control	Biochar	Lime	SEM	*P*-value
N Intake	91.3	92.1	93.5	1.2	0.46
N Retention[3]	16.1	16.3	16.4	0.3	0.60
N Excretion[4]	75.2	75.8	77.0	1.0	0.42
Manure N, % of DM[5]	1.57[ab]	1.71[a]	1.51[b]	0.06	0.07
Manure N[6]	34.0	33.6	37.1	1.3	0.15
N Lost	41.3	42.3	39.9	1.9	0.68
N Lost, %[7]	54.9	55.7	51.7	2.0	0.37
P Intake	18.7	18.9	19.2	0.3	0.43
P Retention[8]	3.9	4.0	4.0	0.1	0.60
P Excretion[9]	14.8	14.9	15.2	0.2	0.38
Manure P, % of DM[10]	0.69	0.76	0.69	0.031	0.23
Manure P[11]	14.8	14.5	15.4	0.8	0.75
P Lost	0.01	0.40	-0.19	0.80	0.87
P Lost, %[12]	-0.1	2.7	-1.3	5.3	0.87
DM Removed	985	794	994	78.5	0.17
OM Removed	348	319	372	30.3	0.48

[1]Values expressed as lb/steer over entire feeding period (186 days on feed)

[2]Control = no treatment applied; Biochar = red cedar biochar applied in Dec and Feb at 270 lb per pen for each application; Lime = applied 1 d prior to cattle harvest

[3]Calculated using the NRC net energy and net protein equations

[4]Calculated as N intake—N retention

[5]Total N in manure as % of manure DM

[6]Manure N with correction for soil N

[7]Calculated as N lost divided by N excretion

[8]Calculated using the NRC phosphorus retention equation

[9]Calculated as P intake—P retention

[10]Total P in manure as % of manure DM

[11]Manure P with correction for soil P

[12]Calculated as P lost divided by P excretion

[ab]Means within a row with different superscripts differ

Table 6. Effect of biochar as a pen amendment on nitrogen (N), phosphorus (P) and organic matter (OM) during SUMMER[1]

	Treatments[2]			
	Control	Biochar	SEM	*P*-value
N Intake	95.7	96.9	1.3	0.35
N Retention[3]	14.4	15.1	0.3	0.04
N Excretion[4]	81.3	81.8	1.1	0.67
Manure N, % of DM[5]	2.01	2.20	0.06	0.07
Manure N[6]	23.1	24.8	4.0	0.78
N Lost	58.2	57.0	4.3	0.85
N Lost, %[7]	71.6	69.6	5.0	0.79
P Intake	21.6	21.9	0.2	0.35
P Retention[8]	3.5	3.7	0.1	0.03
P Excretion[9]	18.1	18.2	0.2	0.69
Manure P, % of DM[10]	1.06	1.13	0.06	0.36
Manure P[11]	16.5	16.1	2.3	0.90
P Lost	1.6	2.1	2.4	0.88
P Lost, %[12]	8.5	11.4	13.1	0.88
DM Removed	589	515	36.6	0.08
OM Removed	258	256	11.4	0.87

[1]Values expressed as lb/steer over entire feeding period (153 days on feed)

[2]Control = no treatment applied; Biochar = red cedar biochar applied in June and Aug at 270 lb per pen for each application

[3]Calculated using the NRC net energy and net protein equations

[4]Calculated as N intake—N retention

[5]Total N in manure as % of manure DM

[6]Manure N with correction for soil N

[7]Calculated as N lost divided by N excretion

[8]Calculated using the NRC phosphorus retention equation

[9]Calculated as P intake—P retention

[10]Total P in manure as % of manure DM

[11]Manure P with correction for soil P

[12]Calculated as P lost divided by P excretion