Using Coal Char from Sugar Production in Cattle Manure Management

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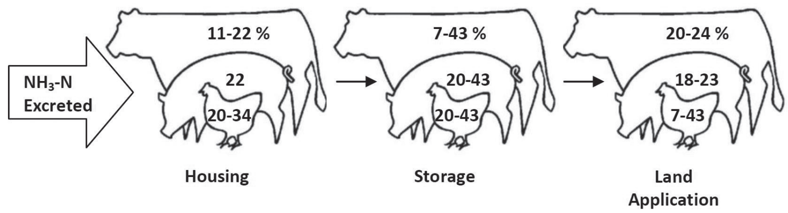

Figure 1. Percent ammonia emissions from total manure-ammonia in each component of livestock operation (EPA National Emissions Estimates, 2005).

Summary with Implications

Application of coal char, a coal combustion residue from the sugar factory in Scottsbluff, NE (containing up to 30 % C by weight), was evaluated as a nitrogen (N) loss mitigation tool for feedlot manure in three experiments. In experiment 1, when char was added to piled manure previously removed from feedlot pens, N loss potential was reduced (44% vs. 68% in the control). In experiment 2, manure was collected fresh from the animal, from the pen surface with cattle still in the pen, and from a pile removed from the pen. Char was mixed with these samples in replicated buckets. Total N in manure samples was in order of fresh > pen > pile in the control treatment (no char) on all three sampling events in this 100-day experiment. In char added samples, total N in piled manured was always less than in fresh or pen manure. Total N in fresh and pen manure was similar on 2 occasions out of 3 sampling events. In experiment 3, char (0.625 ton/head) was applied to the pen surface prior to housing cattle in the pens and compared to pens with no char. Steers were fed a common dry rolled corn-based diet for 218 days. Moisture meters indicated pens with char were drier than pens without. Final body weight, daily gain, dry matter intake, and efficiency were not different due to pen treatment. These data indicate applying char from the sugar beet factory to feedlot pen surfaces may be a N loss mitigation strategy.

Introduction

Coal char is a coal combustion residue (CCR) from a sugar factory in Scottsbluff, NE. Unlike regular CCR from coal-fired power plants, this char contains up to 30 % C by wt. and some plant essential nutrients such as N, P, K, Ca, S, Zn, and Fe. It contains heavy metals (As, Cd, Cr, Pb, Hg, and Se), but their concentrations are below the US EPA's ceiling concentration limits for soil contamination or phytotoxicity in soil. Coal char has a pH of 7.6, surface area of 400 sq ft/ ton, and cation exchange capacity of 47 meq/100g.

In manure management, depending on method and duration of storage, there is a potential risk of significant loss of N which is a valuable crop nutrient (Figure 1). In open cattle feedlot operation, the partitioning of ammonia loss at different stages can be 90/5/5 (housing/storage/land application), which underscores the importance of management intervention at early stages of manure handling for a N loss mitigation strategy. Lignite, when applied on the pen surface, has been demonstrated to reduce ammonia volatilization from cattle feedlot manure by 66 % through its strong acidity (pH 3.69), strong adsorption of ammonium as well as biological immobilization due to high carbon content. Coal char discussed in the paper comes from sub-bituminous coal.

The recommended C:N ratio for feedlot and dairy manure is between 25 and 40:1. At lower C:N ratios, ammonia losses are increased because the energy substrate for microbial growth is limiting. Between 60% and 75% of the N consumed by the animal is lost to volatilization after being excreted until it is applied to fields. Increasing the C:N ratio of feedlot manure has been successful in reducing the amount of N lost from the feedlot. Since coal char contains up to 30% C, it might shift microbial process towards N conservation in manure when mixed in with manure. Additionally, the char might also physically retain N by electrostatic adsorption to its exchange sites. Previous research has shown char at optimal rates reduced ammonia volatilization loss in fertilized soil in a laboratory setting.

Strategies to mitigate ammonia emissions from feedlot operations may involve changing diet formulation, using additives or management to alter soil and storage conditions of manure. However, these strategies are cost-prohibitive in most cases and hence, lack wide adoption. The char from Western Sugar has the potential to be an economic solution in this regard.

The objective of these experiments was to evaluate coal char as a manure amendment to reduce N loss at various stages of manure handling and storage before land application.

Procedure

Experiment 1. Manure from pens was scraped and piled on a cement apron, sampled, weighed, and hauled to the manure storage plot in the spring 2017. Eight piles were constructed with 4 piles receiving char and 4 control piles. Each pile weighed about 2600 lbs. The char and manure mixture pile (CHAR treatment) had 1600 lbs of manure and 1000 lbs of char. The CHAR treatments were mixed using a rototiller. Samples were collected on d 0 during pile construction from the control (CON) and char (CHAR)

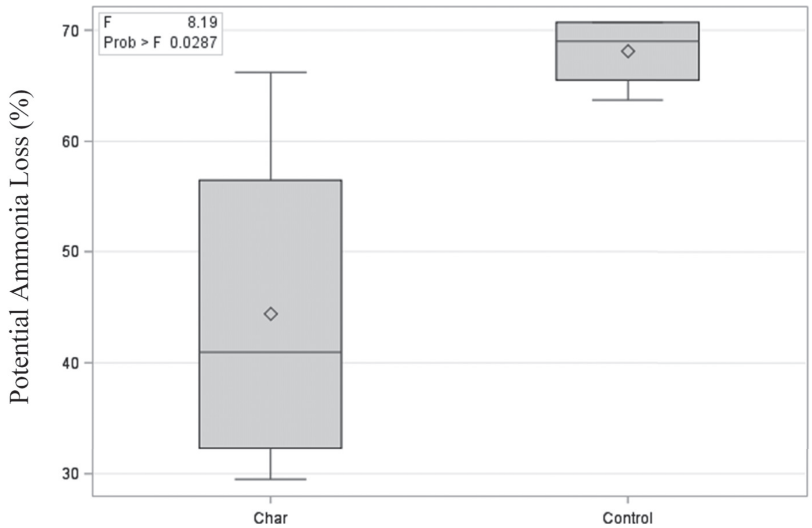

Figure 2. Distribution (and average; diamond) of ammonia loss potential under manure only (CON) and char-treated manure (CHAR) treatments (Experiment 1).

Table 1. Moisture and Potential Ammonia Loss by treatments in the Experiment 1.

Treatment	Rep	Moisture (%)	Ammonium-N (lbs), 24 hr @ 212 F before	Ammonium-N (lbs), 24 hr @ 212 F after	Potential Ammonia loss (%)
Manure	1	25.61	2.64	0.96	64
Manure	2	27.68	2.73	0.80	71
Manure	3	24.73	3.25	1.06	67
Manure	4	22.56	2.81	0.82	71
Manure+Char	1	23.74	1.30	0.84	35
Manure+Char	2	31.27	2.72	0.92	66
Manure+Char	3	26.45	1.96	1.04	47
Manure+Char	4	25.47	2.11	1.49	30

Treatment included Control (manure only) and Char (manure mixed with char).

treatments. Ammonium-N was measured on samples as-is and after drying for 24 h in a 212° F oven to determine the ammonia volatilization potential. Effect of treatments (CHAR and CON) on N loss potential was evaluated by using Analysis of Variance (ANOVA) test in SAS.

Experiment 2. Manure was collected at three stages; freshly deposited from cattle in pens, manure from the pen surface while cattle were still housed in the pen, and manure scraped out of pens when cattle were removed and piled on ground for storage. Eight 5-gallon buckets were filled with manure collected at each sampling stage with 4 buckets receiving char (treatment CHAR) and 4 manure only (control treatment, CON) buckets. Char was added to manure in 1:1 ratio (dry wt.). A few 2-cm holes were drilled at bottom of buckets to avoid water ponding in the events of rainfall during the experiment and filter paper was spread at bottom of buckets before adding char and manure to avoid any loss of treatment materials. Samples from each bucket were collected using soil probes on d 33, d 66 and d 100. Samples were analyzed for organic N, ammonium N, nitrate N and total N as well as organic carbon and minerals. Effects of treatments on manure N and other nutrients were determined by using Proc Mixed test in SAS where manure stages (fresh, from pens and pile), and char treatment (CHAR and CON) were the main effects.

Experiment 3. The experiment was conducted in a completely randomized design with 5 replications. Treatments were char (0.625 ton/head; CHAR) or no char (0 ton/ac; CON). Char was spread uniformly within the cattle pens prior to cattle being housed in the pens. Soil moisture sensors were installed at 5 in depth in one pen from each treatment. Pens were assigned randomly to treatment. Steers (n=100; initial wt=703±15.6 lb) were stratified by weight and assigned to pen. Prior to trial initiation, steers were limit fed (2% BW) a common diet to reduce gut fill and weight variation for 5 days. Steers were then weighed two consecutive days and the weight average was used as the initial weight for the experiment. Steers were fed a common dry-rolled corn based finishing diet for 218 d. At the end of the feeding period, cattle were weighed on a pen scale and assessed a 4% shrink on live weight. Cattle were then harvested at a commercial abattoir. Sub samples of the manure scraped from the pens were analyzed for nutrient contents.

Results

Experiment 1. Ammonia volatilization potential was significantly lower for CHAR (44%) compared with CON (68%) (*P* = 0.03) (Figure 2). One replication of the CHAR treatment had 66% ammonia loss potential, close to the average of manure only CON treatment because of its higher moisture content (31%) compared to the rest of the replications (23-26%) (Table 1). The higher the moisture content, the greater the evaporative loss of ammonia.

Experiment 2. Total N in manure samples was in order of fresh > pen > pile in the control treatment (no char) on all 3 sampling events in this 100-day experiment (Figure 2). Compared to fresh manure, piled and pen manure had total N less by around 51 and 34% respectively. In char added samples, total N in piled manured was always less than in fresh or pen manure. Total N in fresh and pen manure was similar on 2 occasions out of 3 sampling events. Compared to fresh manure, piled and pen manure had total N less by around 38 and 10 % respectively in the CHAR

Table 2. Percentage gain in different elemental concentrations in manure samples due to char addition in the Experiment 2.

Manure	ΔCa	ΔMg	ΔNa	ΔFe	ΔCu	ΔB
Fresh	260	129	20	1052	344	475
Pen	119	76	-23	113	325	274
Pile	176	55	-26	232	202	235

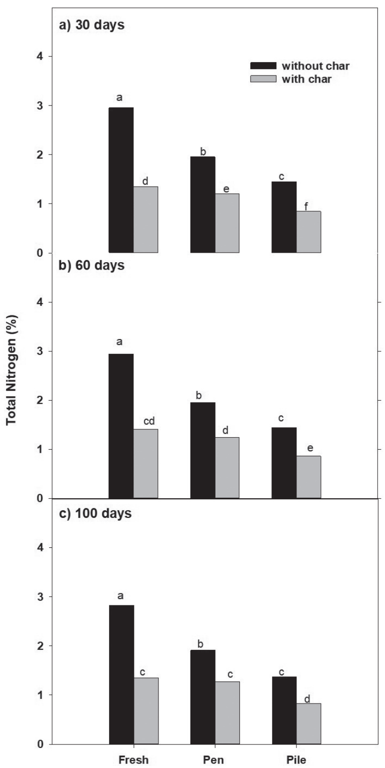

Figure 3. Total N over the period of 100 days after collecting samples from different stages; fresh, pile and pen on a) 30 days, b) 60 days, and c) 100 days. Means with different small letters in each plate are significantly different at $P < 0.05$.

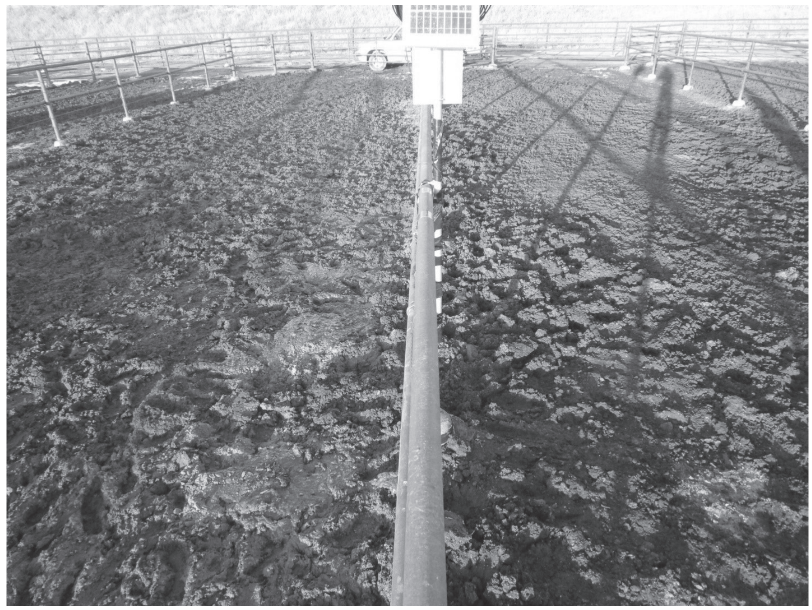

Figure 4. Moisture conditions in the control (left) and the char treatment (right) following Nov. storm.

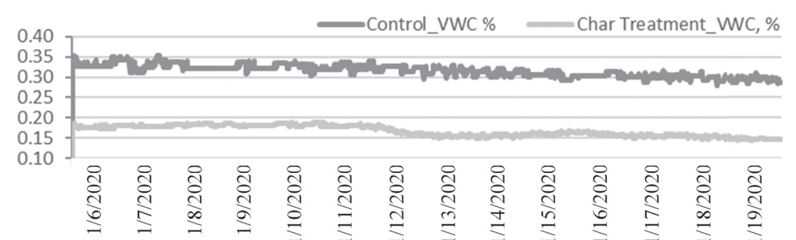

Figure 5. Volumetric water content (VWC) under the no-char and char-applied cattle pens in first half of January 2020.

treatments. It is important to note that total N in the CHAR treatments is not adjusted for added char.

Early the better for management inventions to reduce N loss from manure. However, adding char to fresh manure is not feasible in cattle manure operation. Nitrogen loss portioning in this experiment suggests most of N is lost while collecting in the pen and adding char directly to the pen is a worth an investigation. Adding char to manure samples has another potential benefit of increasing several crop beneficial nutrients such as Ca, Mg, Fe, Cu, and B and decreasing Na (Table 2).

Experiment 3. The pens with CHAR were drier than CON after a series of snowstorms in November (Figures 4). Soil moisture sensor data showed drier pens in CHAR compared with CON (Figure 5). At the end of the experiment, the CHAR treatment was targeted to have a mix of manure and char approximately at 2:1. To achieve that, 12,500 lbs of char was applied to each pen anticipating 25,000 lbs of manure from 10 head. Chemical analysis of the samples collected from the pens with or without char showed decrease in organic, ammonium and total N and P and S in CHAR treatment compared to the control (Table 3).The decrease in those values in the CHAR treatment does not necessarily mean nutrient loss since those values in the CHAR treatment were not adjusted for added char. Moisture levels were significantly lower in the CHAR than in the control treatment. Lower moisture content eases

Table 3. Chemical analysis of manure samples from the pens with or without char application in Experiment 3.

Treatment	Moisture	Organic N	NH4-N	Total N	P	S	Ca	Mg	Zn	Fe	Cu	B	pH
	%								ppm				
CON	31.8a	1.71a	0.03	1.73a	1.66a	0.41a	3.51	0.91	145	8236	41	42	8.1
CHAR	26.0b	1.49b	0.03	1.52b	1.46b	0.36b	3.36	0.86	141	9027	31	40	8.1
P value	<0.0001	<0.0001	0.965	<0.0001	0.025	0.02	0.79	0.63	0.77	0.46	0.43	0.88	0.97

Treatment included Control (manure only) and Char (manure mixed with char).

Means in each column followed by different small cap letters are significantly different at given *P* values.

Table 4. Performance of finishing steers housed in pens with or without char application (Experiment 3).

	CHAR	CONTROL	SE	*P* value
Initial BW, lb	703	703	15.6	0.99
Final BW, lb	1385	1393	20.3	0.79
Daily gain, lb/d	3.98	4.04	0.05	0.51
Dry matter intake, lb/d	25.5	26.0	0.41	0.41
F:G	6.39	6.44		0.72

Treatment included Control (manure only) and Char (manure mixed with char).

the transport and land application of the mix compared to manure only.

There were no significant differences ($P > 0.41$) in initial or final body weight, average daily gain, dry matter intake, or F:G for CHAR vs. CON (Table 4).

Conclusions

Since ammonia from feedlots is a significant source of lost N, reducing emissions from feedlots will achieve local environmental benefits. Data from this study demonstrated a viable use of coal char in manure management, particularly in the pen to reduce nutrient loss and improve manure nutrient contents without impacting cattle performance.

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