Concentrations of fecal bacteria and nutrients in soil surrounding round-bale feeding sites[1,2]

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ABSTRACT: An experiment was conducted over 7 mo (January to July 2003) to evaluate fecal bacteria and nutrient concentrations in soil surrounding round-bale feeders at 10 winter feeding sites. Soil samples 15 cm in depth were taken monthly from each site at distances of 3, 12, 21, and 30 m from the feeder. Soil samples were taken before livestock access to the sites (January), during the feeding period (February, March, and April), and after cattle removal from the sites (May, June, and July). Results indicated that fecal bacteria concentrations increased over the feeding period and were greatest at close proximity to round-bale feeders. Fecal *Escherichia coli* concentrations were greater in April ($P < 0.03$) at 3 and 12 m than in all other months, except March. At 21 and 30 m from the feeders, fecal *E. coli* concentrations were greater in April ($P < 0.01$) than in other months. At 3 m from the feeder, fecal *Streptococci* concentrations were greater in March and April ($P < 0.01$) than in other months. Although fecal *E. coli* concentrations in July had returned to levels similar to those in the prefeeding period, fecal *Streptococci* remained at higher concentrations ($P < 0.05$) than at the prefeeding period. The concentration of soil P at 3 m was greater in April ($P < 0.02$) than in January, February, and May. After cattle access to the sites, soil DM content was consistently less for samples taken at 3 m from the feeder compared with the other distances, with quadratic decreases ($P < 0.02$) noted in March, April, and July, and linear decreases ($P < 0.01$) in May and June, as distance from the feeder decreased.

Key Words: Cattle, Environment, Fecal Bacteria, Feeding Sites, Manure, Nutrients

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Introduction

The use of temporary feeding sites during winter and early spring months to supply supplemental forage and offer protection from harsh weather is a common practice among beef producers. Round-bale feeders are a common method of containing forage at feeding sites (Taylor et al., 1995); however, little is known about the environmental impacts of this practice. It is known that grazing livestock can affect water quality if livestock are not appropriately managed (Moore et al., 1979). Several studies involving grazed pastures have noted increases in coliform concentrations in surrounding water sources soon after the introduction of cattle to the sites (Coltharp and Darling, 1975; Stephenson and Street, 1978; Doran and Linn, 1979). Research to determine the environmental impact on soil surrounding feeding sites is lacking. Therefore, our objective was to determine the changes in fecal bacterial and nutrient concentrations in soil surrounding round-bale feeding sites to provide insight into the environmental impact of this feeding practice.

Materials and Methods

General

Ten native-range winter feeding areas using round-bale feeders (conventional, 2.4 m diameter) located in Riley, Washington, and Wabaunsee Counties in northeast Kansas were used in 2003. All sites selected had not been used previously as a feeding location. The numbers of cows varied at each site, with a range of 11 to 18 cows that had access to each feeder during the experimental period (mean of 15.2 cows per feeder). Four of the testing sites had one feeder, one site had two feeders that were 150 m apart, and one site had four feeders that were 60 m apart. Soil samples were taken (during the first week of each month) before livestock access to the sites (January), during the feeding period (February, March, and April), and after cattle removal

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from the sites (May, June, and July). Twelve to fifteen 15-cm core soil samples were taken and mixed into a single composite within each distance (3, 12, 21, and 30 m) surrounding each round-bale feeder (10 sites) at each sample date.

In some locations, producers supplied supplemental feed and free-choice trace minerals outside of the 30-m testing area of the bale feeders; however, there was no indication that supplemental feed and minerals affected the soil nutrient analysis data in this experiment.

Soil Bacteria Analyses

Soil was analyzed for fecal coliforms, fecal *Escherichia coli*, and fecal *Streptococci*. Subsamples of soil for fecal bacteria analyses were mixed thoroughly with sterile water or physiological saline and were subsampled for analysis of fecal coliforms, *E. coli*, and fecal *Streptococci*. A membrane filter technique was used for all bacteriological assays (APHA, 1985). For fecal *Streptococci*, KF strep agar (Difco, Franklin Lakes, NJ) was prepared according to manufacturer instructions, and 10 mL of 10% (vol/vol) triphenyltetrazolium chloride was added aseptically. Media were poured into 60 × 15 mm polystyrene Petri dishes and allowed to solidify. Various amounts of the aqueous suspension of soil were added to nitrocellulose filters in filter apparatus. Filters were then placed on the KF agar plates and incubated for 48 h at 35 ± 0.5°C. Red to pink colonies were counted in a range of 20 to 100 cfu. Fecal coliforms were counted with a similar membrane filter technique, except that the media were membrane fecal coliforms (M-FC; Difco) for selection of fecal coliforms, and the incubation period was 44.5 ± 0.2°C for 24 h. The *E. coli* were enumerated by transferring membrane filters from the M-FC medium to nutrient agar with 4-methylumbelliferyl β-D-glucuronide and incubating for an additional 4 h at 35 ± 0.5°C. Plates were examined with a long-wave UV light source (366 nm), and colonies with a blue fluorescence were classified as *E. coli*. The minimum indication level was approximately 30 cfu/mL, whereas the maximum cutoff level was 300 cfu/mL because values generating this number made counting impractical. Fecal bacteria concentrations are expressed as $\log_{10}$ cfu/g of soil DM.

Soil Nutrient Analyses

Soil samples were analyzed for P (Bray P-1), N, S, Zn, Cu, K, Ca, Mg, Na, Fe, Mn, OM, and DM (NCRR, 1998).

Statistical Analyses

The effects of sampling site distance from the round-bale feeder, sampling month, and their interaction was evaluated using repeated-measures Mixed model analysis in SAS (SAS Inst. Inc., Cary, NC) in a completely randomized design. The best-fitting covariance structure was chosen using the Akaike's information criterion (Littell et al., 1996) for each response criteria to account for heterogeneity of variance for some variables. Linear and quadratic contrasts were used to evaluate the effects of distance within each month of sampling. All soil bacteria and nutrient values were adjusted for DM content before statistical analysis. Furthermore, due to lack of evidence of normality for bacterial concentrations, the log of soil bacterial concentration was used for all statistical analyses.

Results

Interaction between distance and month of sample collection was significant ($P < 0.05$) for all response criteria evaluated. Therefore, all data are presented as interactive means.

Soil Fecal Bacteria Concentrations

As expected, there was few or no fecal coliforms present at any distance in January, which was before the introduction of cattle to the feeding site (Table 1). Fecal coliform concentrations in samples collected at 3 and 12 m were greater ($P < 0.01$) in March, April, and May than in the other months. In addition, fecal coliforms concentrations at 21 and 30 m were greater in April ($P < 0.01$) than in other months sampled, with May having greater ($P < 0.04$) concentrations than other months, except March. Linear increases ($P < 0.04$) in fecal coliforms were observed for February, April, May, and June, whereas a quadratic response ($P < 0.04$) was observed in March and July, as distance from the feeder decreased. In July, 3 mo after cattle had been removed from the sites, no fecal coliforms were detected at 12, 21, or 30 m. Concentrations of fecal coliforms at 3 m were greater in July than in the prefeeding period.

Fecal *E. coli* concentrations at 3 and 12 m from the feeder were greater in April ($P < 0.03$) than in other months, except March. At 21 and 30 m from the feeder, *E. coli* concentrations were greater in April ($P < 0.01$) than in other months. A quadratic increase ($P < 0.04$) was observed for *E. coli* concentrations in March as distance from the feeder decreased, whereas linear increases ($P < 0.02$) occurred in the remaining months of the study.

At a distance of 3 m from the feeding area, fecal *Streptococci* concentrations were greater in March and April ($P < 0.01$) than in other months. Fecal *Streptococci* concentrations at 12 m were greater in March ($P < 0.01$) than in January, February, June, and July. At 30 m from the feeder, concentrations of fecal *Streptococci* were greater in July ($P < 0.01$) then in January, February, March, and June. There was a quadratic increase ($P < 0.01$) in fecal *Streptococci* concentrations in February, April, and July, whereas there was a linear increase ($P < 0.03$) in fecal *Streptococci* concentrations in January and March as distance from the feeder decreased.

Soil Nutrient Concentrations

The concentration of N in the soil at 3 m from the feeder was greater in July ($P < 0.01$) than in other

Table 1. Influence of month and distance from bale feeders on bacteria concentrations of the soil (DM basis)[a]

	Month[b]							
Item, log10 cfu/g	Jan	Feb	Mar	Apr	May	Jun	Jul	SE
Fecal coliforms								
3 m	0^{c}	0.66^{cd}	3.38^{f}	3.68^{f}	3.02^{f}	1.51^{e}	0.77^{de}	0.40
12 m	0.11^{c}	0.21^{c}	1.89^{d}	2.32^{d}	1.61^{d}	0.42^{c}	0^{c}	0.40
21 m	0.41^{c}	0.16^{c}	0.68^{cd}	2.38^{e}	1.40^{d}	0.40^{c}	0^{c}	0.40
30 m	0^{c}	0^{c}	0.47^{cd}	2.17^{e}	0.83^{d}	0^{c}	0^{c}	0.40
Probability ($P <$)								
Linear	0.60	0.04	0.001	0.004	0.001	0.001	0.01	
Quadratic	0.05	0.50	0.03	0.07	0.20	0.19	.04	
SE	0.12	0.21	0.31	0.45	0.36	0.30	0.19	
Fecal *E. Coli*								
3 m	0^{c}	0.45^{c}	3.36^{ef}	3.67^{f}	2.67^{e}	1.49^{d}	0.69^{c}	0.38
12 m	0.11^{c}	0^{c}	1.73^{de}	2.25^{e}	1.40^{d}	0.41^{c}	0^{c}	0.38
21 m	0.11^{c}	0^{c}	0.68^{cd}	2.32^{e}	1.16^{d}	0.40^{c}	0^{c}	0.38
30 m	0^{c}	0^{c}	0.30^{c}	2.14^{d}	0.65^{c}	0^{c}	0^{c}	0.38
Probability ($P <$)								
Linear	1.00	0.06	0.001	0.004	0.001	0.001	0.02	
Quadratic	0.17	0.15	0.03	0.06	0.20	0.20	0.07	
SE	0.08	0.15	0.32	0.45	0.35	0.30	0.18	
Fecal *Streptococci*								
3 m	0.85^{c}	2.80^{d}	3.82^{e}	4.12^{e}	2.67^{d}	1.14^{c}	2.53^{d}	0.41
12 m	0.32^{c}	1.57^{d}	2.65^{e}	2.26^{de}	1.90^{de}	0.58^{c}	1.83^{d}	0.41
21 m	0.36^{c}	0.83^{cd}	1.79^{e}	2.02^{e}	2.10^{e}	0.82^{cd}	1.41^{de}	0.41
30 m	0.17^{c}	1.11^{de}	0.97^{cde}	1.67^{ef}	1.60^{ef}	0.42^{cd}	1.93^{f}	0.41
Probability ($P <$)								
Linear	0.02	0.001	0.001	0.001	0.06	0.09	0.03	
Quadratic	0.35	0.004	0.42	0.01	0.69	0.73	0.01	
SE	0.22	0.28	0.23	0.27	0.39	0.33	0.31	

[a]Soil samples were taken from 3- 12-, 21-, and 30-m distances from each round-bale feeder.
[b]January (Jan) before feeding; February (Feb), March (Mar), and April (Apr) feeding period; and May, June (Jun), and July (Jul) postfeeding period.
[c,d,e,f]Within a row, means without a common superscript letter differ, $P < 0.05$.

months, except June (Table 2). At 12 m, the concentration of soil N was greater in March ($P < 0.03$) than concentrations in January, May, June, and July. At 21 m, the concentration of soil N was higher in March ($P < 0.03$) than in April, May, June, and July. There was a quadratic increase ($P < 0.02$) in soil N concentration in March, June, and July as distance from the feeder decreased.

Soil OM concentrations were greater in March ($P < 0.05$) at 3 m then in January and February. At both 12 and 21 m, concentrations of OM were greater in July ($P < 0.05$) than in other months. The level of OM at 30 m was greater in July ($P < 0.05$) than in January, February, April, and June. A linear increase ($P < 0.02$) in OM occurred in March and June as distance from the feeder decreased, whereas a quadratic increase ($P < 0.02$) was noted in April.

Soil DM percent at 3 m from the feeder was greater in July ($P < 0.05$) than in January, March, April, and May. At 12, 21, and 30 m, soil DM was greater in July ($P < 0.05$) than in other months of the study. There were quadratic decreases ($P < 0.02$) in DM in March, April, and July as distance from the feeder decreased, whereas linear decreases ($P < 0.01$) were observed in May and June.

The concentration of soil P at 3 m was greater in April ($P < 0.02$) than in January, February, or May (Table 3). There were no differences in soil P concentrations observed at 12, 21, or 30 m from the feeder over the entire experiment. There were linear increases ($P < 0.02$) of P in the soil in March, April, June, and July as distance from the feeder decreased.

Concentrations of S in the soil at 3 m from the feeder were greater in March ($P < 0.05$) than in other months. In addition, S concentrations at 12 m were greater in February ($P < 0.05$) then in January, March, June, or July. Sulfur concentrations at 21 and 30 m did not differ over the testing period. There was a quadratic increase ($P < 0.05$) for January, March, April, June, and July, and linear increases ($P < 0.04$) for February and May for concentrations of S in the soil as distance from the feeder decreased.

The concentration of K in the soil at 3 m was greater from March to July ($P < 0.01$) than in January or February. Potassium concentrations at 12, 21, and 30 m did not differ during the experiment. There were linear increases ($P < 0.05$) in K concentrations in January, February, and May, and quadratic increases ($P < 0.01$) in other months, as distance from the feeder decreased.

Table 2. Influence of month and distance from bale feeders on soil nitrogen and properties[a]

	Month[b]							
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	SE
N (DM basis), ppm								
3 m	30.74[c]	24.30[c]	27.36[c]	8.77[d]	25.94[c]	53.06[e]	70.26[e]	8.99
12 m	22.69[c]	32.94[cd]	48.01[d]	33.78[cd]	20.57[c]	21.74[c]	28.02[c]	8.99
21 m	29.67[cd]	29.68[cd]	46.59[d]	19.20[c]	24.55[c]	16.74[c]	25.65[c]	8.99
30 m	28.34	27.31	29.90	25.89	15.78	19.31	26.42	8.99
Probability ($P <$)								
Linear	0.99	0.83	0.83	0.14	0.46	0.001	0.002	
Quadratic	0.46	0.35	0.008	0.10	0.83	0.004	0.02	
SE	6.20	7.99	8.65	6.62	8.23	6.12	10.25	
OM (DM basis), %								
3 m	5.23[c]	5.85[cd]	7.18[e]	6.37[de]	5.97[cde]	6.36[de]	6.73[de]	0.46
12 m	5.49[cd]	5.51[cd]	6.03[d]	4.69[c]	5.54[cd]	5.60[d]	7.12[e]	0.46
21 m	5.51[cd]	5.23[d]	6.16[c]	4.76[d]	5.29[cd]	5.40[cd]	6.59[e]	0.46
30 m	5.44[cd]	5.43[cd]	5.95[ce]	4.75[d]	5.71[ce]	5.12[cd]	6.55[e]	0.46
Probability ($P <$)								
Linear	0.54	0.37	0.01	0.003	0.37	0.02	0.46	
Quadratic	0.48	0.48	0.09	0.02	0.11	0.54	0.50	
SE	0.42	0.43	0.42	0.44	0.41	0.40	0.38	
DM, %								
3 m	83.94[c]	79.12[de]	76.95[ef]	75.71[f]	74.61[f]	78.79[de]	79.69[d]	1.41
12 m	84.12[c]	80.27[d]	82.37[cd]	81.28[d]	81.47[cd]	81.83[cd]	87.42[e]	1.41
21 m	84.09[c]	80.94[d]	82.64[cd]	81.50[cd]	80.76[d]	82.67[cd]	87.96[e]	1.41
30 m	83.73[c]	81.00[d]	83.17[cd]	81.83[cd]	81.55[cd]	83.81[c]	88.14[e]	1.41
Probability ($P <$)								
Linear	0.78	0.10	0.001	0.001	0.01	0.002	0.001	
Quadratic	0.60	0.52	0.02	0.001	0.06	0.38	0.001	
SE	0.84	1.10	1.14	1.09	1.58	1.05	1.32	

[a]Soil samples were taken from 3-, 12-, 21-, and 30-m distances from each round-bale feeder.
[b]January (Jan) before feeding; February (Feb), March (Mar), and April (Apr) feeding period; and May, June (Jun), and July (Jul) postfeeding period.
[c,d,ef]Within a row, means without a common superscript letter differ, $P < 0.05$.

The concentrations of soil Ca at 3 and 12 m were greater in July ($P < 0.04$) than in January, May, and June. At 21 m, the concentration of soil Ca was greater in July ($P < 0.01$) than in January or June. At 30 m, the concentration of soil Ca in March was greater ($P < 0.03$) than in January, May, or June. There were linear increases ($P < 0.01$) in soil Ca concentrations for all testing periods of the experiment as distance from the feeder increased.

Magnesium concentrations present at 3 m were greater in July ($P < 0.05$) than in other months, except April. At 12 and 30 m, the concentrations of soil Mg were greater in February ($P < 0.05$) than in June. Concentration of soil Mg at 21 m in July was greater ($P < 0.01$) than in January. In April and May, there was a quadratic increase ($P < 0.01$) in soil Mg concentrations as distance from the feeder decreased, and there were linear increases ($P < 0.01$) in soil Mg in March, June, and July.

Soil Na concentration at 3 m from the feeder was greater in April ($P < 0.01$) than in January, February, May, or July. At 12 m, concentrations of soil Na were greater in June ($P < 0.02$) than concentrations in January or July. At 21 m, the soil Na concentration was greater in April ($P < 0.05$) than in January, and at 30 m, the concentration was greater in June ($P < 0.04$) than the concentration in May and July. There were quadratic increases ($P < 0.03$) in soil Na in January, March, April, and June, and linear increases ($P < 0.02$) in February, May, and July, as distance from the feeder decreased.

Concentration of Zn in the soil at 3 m from the feeder was greater in July ($P < 0.05$) than in all other months, except March (Table 4). At 12 m from the feeder, the soil Zn concentration was greater in July ($P < 0.05$) than in January, February, March, or June. Zinc concentrations at 21 m were greater in April ($P < 0.05$) than in January, February, or June. At 30 m from the feeder, the soil Zn concentration was greater in July ($P < 0.05$) then in January, February, or June. There were linear increases ($P < 0.05$) in Zn concentrations in March, June, and July as distance from the feeder decreased.

Concentration of Cu in the soil at 3 m in June and July was greater ($P < 0.01$) than in other months. At 12 m, the concentration of Cu in the soil was greater in February ($P < 0.01$) than in January, May, and July. Copper concentrations in the soil at 21 and 30 m were greater in February and April ($P < 0.05$) than concentrations in January. There was a quadratic increase ($P < 0.03$) in concentrations of Cu in the soil in the months from March to July, as distance from the feeder decreased.

Iron concentrations in the soil at 3 m were greater in July ($P < 0.01$) than concentrations from January

Table 3. Influence of month and distance from bale feeders on soil macromineral concentrations (DM basis)[a]

Item	Month[b]							SE
	Jan	Feb	Mar	Apr	May	Jun	Jul	
P, ppm								
3 m	63.66[c]	65.68[c]	121.92[de]	154.31[e]	93.28[cd]	129.37[de]	129.17[de]	25.13
12 m	40.96	83.17	58.89	62.84	64.3	52.86	66.41	25.13
21 m	37.79	39.32	47.02	58.29	71.44	44.53	46.41	25.13
30 m	44.67	48.18	54.93	52.71	54.44	39.00	53.21	25.13
Probability (*P* <)								
Linear	0.39	0.27	0.02	0.003	0.15	0.01	0.02	
Quadratic	0.35	0.82	0.08	0.06	0.72	0.14	0.11	
SE	19.93	25.49	25.26	26.47	21.3	28.67	26.27	
S, ppm								
3 m	11.50[c]	27.86[d]	72.59[f]	42.60[de]	37.22[de]	41.08[de]	44.90[e]	8.00
12 m	5.95[c]	25.89[d]	9.92[c]	11.87[cd]	11.37[cd]	7.30[c]	8.90[c]	8.00
21 m	6.10	6.86	7.93	7.90	17.2	8.72	6.28	8.00
30 m	11.53	8.57	8.83	8.18	6.87	12.04	7.58	8.00
Probability (*P* <)								
Linear	0.98	0.04	0.001	0.001	0.01	0.001	0.001	
Quadratic	0.05	0.82	0.001	0.001	0.25	0.001	0.01	
SE	4.11	8.09	7.99	4.23	6.60	4.96	6.89	
K, ppm								
3 m	1,042[c]	1,603[c]	2,484[d]	2,556[d]	2,435[d]	2,552[d]	2,701[d]	297.7
12 m	798	1,162	998	1,098	1,109	946	1,025	297.7
21 m	735	791	876	844	1,256	783	778	297.7
30 m	671	752	766	816	862	721	788	297.7
Probability (*P* <)								
Linear	0.05	0.004	0.001	0.001	0.001	0.001	0.001	
Quadratic	0.48	0.33	0.002	0.001	0.11	0.01	0.01	
SE	153	209	214	217	287	264	334	
Ca, ppm								
3 m	3,847[cd]	4,384[cdef]	4,464[def]	4,612[ef]	4,216[cde]	3,756[c]	4,917[f]	333.8
12 m	4,193[cd]	4,749[cdef]	4,836[def]	5,106[ef]	4,347[cd]	4,166[c]	5,126[f]	333.8
21 m	4,130[c]	5,182[de]	4,933[de]	5,081[de]	4,684[cde]	4,224[c]	5,183[e]	333.8
30 m	4,836[c]	5,523[de]	5,829[e]	5,600[de]	5,079[cd]	4,582[c]	5,583[de]	333.8
Probability (*P* <)								
Linear	0.001	0.004	0.001	0.001	0.01	0.003	0.01	
Quadratic	0.30	0.97	0.28	0.95	0.54	0.88	0.56	
SE	644	685	671	576	495	526	570	
Mg, ppm								
3 m	364[c]	429[d]	478[ef]	524[fg]	474[de]	456[de]	543[g]	25.62
12 m	376[c]	440[e]	417[cde]	434[de]	402[cde]	390[cd]	439[de]	25.62
21 m	355[c]	414[de]	408[de]	408[de]	394[cde]	370[cde]	420[e]	25.62
30 m	375[cd]	422[d]	397[cd]	421[d]	403[cd]	356[c]	409[d]	25.62
Probability (*P* <)								
Linear	0.86	0.46	0.002	0.001	0.003	0.004	0.001	
Quadratic	0.76	0.89	0.14	0.01	0.01	0.26	0.06	
SE	24	29	26	26	27	29	33	
Na, ppm								
3 m	41.22[c]	69.61[cd]	126.53[fg]	146.93[g]	86.66[de]	117.29[fg]	101.30[ef]	15.53
12 m	29.00[c]	59.04[de]	61.20[de]	64.40[de]	45.46[cde]	73.65[e]	37.82[cd]	15.53
21 m	28.86[c]	46.09[cd]	56.69[cd]	66.49[d]	49.85[cd]	57.42[cd]	41.23[cd]	15.53
30 m	35.97[cde]	45.79[cde]	61.53[de]	63.07[e]	28.96[c]	66.85[e]	31.99[cd]	15.53
Probability (*P* <)								
Linear	0.28	0.02	0.001	0.001	0.004	0.003	0.01	
Quadratic	0.01	0.52	0.001	0.002	0.40	0.03	0.10	
SE	6.76	10.26	11.94	12.09	13.01	18.12	18.02	

[a]Soil samples were taken from 3-, 12-, 21-, and 30-m distances from each round-bale feeder.
[b]January (Jan) before feeding; February (Feb), March (Mar), and April (Apr) feeding period; and May, June (Jun), and July (Jul) postfeeding period.
[c,d,e,f,g]Within a row, means without a common superscript letter differ, $P < 0.05$.

Table 4. Influence of month and distance from bale feeders on soil micromineral concentrations (DM basis)[a]

Item	Month[b]							SE
	Jan	Feb	Mar	Apr	May	Jun	Jul	
Zn, ppm								
3 m	4.46[c]	4.55[c]	6.41[de]	6.04[d]	5.61[cd]	5.91[d]	7.38[e]	0.65
12 m	4.05[c]	5.03[cd]	5.30[cd]	5.57[de]	6.03[de]	5.16[cd]	6.82[e]	0.65
21 m	4.04[c]	4.15[cd]	5.23[cdef]	6.08[f]	5.35[def]	4.69[cde]	5.73[ef]	0.65
30 m	3.58[c]	4.00[cde]	4.91[def]	5.15[def]	5.19[ef]	3.90[cd]	5.89[f]	0.65
Probability ($P <$)								
Linear	0.16	0.28	0.004	0.28	0.21	0.02	0.05	
Quadratic	0.95	0.54	0.23	0.60	0.40	0.97	0.55	
SE	0.50	0.63	0.64	0.88	0.58	0.79	0.82	
Cu, ppm								
3 m	1.35[c]	1.46[cd]	1.69[d]	2.20[e]	2.10[e]	2.70[f]	2.67[f]	0.13
12 m	1.20[cd]	1.52[e]	1.40[de]	1.44[de]	1.23[cd]	1.43[de]	1.15[c]	0.13
21 m	1.16[c]	1.41[e]	1.34[cde]	1.41[de]	1.31[cde]	1.39[cde]	1.22[cde]	0.13
30 m	1.14[c]	1.44[e]	1.38[cde]	1.44[e]	1.18[cd]	1.40[de]	1.25[cde]	0.13
Probability ($P <$)								
Linear	0.06	0.61	0.005	0.001	0.001	0.001	0.001	
Quadratic	0.39	0.88	0.03	0.001	0.01	0.001	0.001	
SE	0.15	0.16	0.16	0.18	0.19	0.13	0.16	
Fe, ppm								
3 m	79.03[c]	59.70[d]	77.78[cd]	117.71[e]	152.00[f]	196.82[g]	202.58[g]	9.85
12 m	66.28[c]	78.56[cde]	81.12[cde]	84.47[cde]	88.86[e]	85.90[de]	69.31[cd]	9.85
21 m	63.67	72.03	79.01	70.99	77.63	81.19	65.02	9.85
30 m	53.96	64.51	65.61	70.10	67.11	57.90	58.01	9.85
Probability ($P <$)								
Linear	0.002	0.74	0.03	0.001	0.001	0.001	0.001	
Quadratic	0.76	0.02	0.04	0.01	0.01	0.001	0.001	
SE	6.91	6.66	7.20	8.85	11.84	12.43	11.06	
Mn, ppm								
3 m	16.07[c]	37.60[d]	58.21[e]	84.93[f]	84.49[f]	65.29[e]	55.27[e]	7.24
12 m	15.45	22.77	20.41	23.83	20.08	26.78	18.73	7.24
21 m	14.21	19.46	19.65	20.63	22.57	25.22	18.05	7.24
30 m	13.61	19.68	18.29	21.34	17.93	23.80	18.57	7.24
Probability ($P <$)								
Linear	0.04	0.001	0.001	0.001	0.001	0.001	0.001	
Quadratic	0.99	0.03	0.01	0.001	0.002	0.001	0.001	
SE	2.85	5.13	7.69	7.71	9.75	5.19	4.23	

[a]Soil samples were taken from 3-, 12-, 21-, and 30-m distances from each round-bale feeder.
[b]January (Jan) before feeding; February (Feb), March (Mar), and April (Apr) feeding period; and May, June (Jun), and July (Jul) postfeeding period.
[cdefg]Within a row, means without a common superscript letter differ, $P < 0.05$.

through May. At 12 m, concentrations of Fe were higher in May ($P < 0.05$) than in January or July. There were no differences in soil Fe concentrations at 21 and 30 m from the feeder. There were quadratic increases ($P < 0.04$) in Fe concentrations from February through July, and a linear increase ($P < 0.01$) in January as distance from the feeder decreased.

At a distance of 3 m from the feeder, concentrations of Mn in the soil were greater in April and May ($P < 0.01$) than in other months. Soil Mn concentrations at 12, 21, and 30 m did not differ during the experiment. All testing periods except January showed a quadratic increase ($P < 0.03$) in Mn concentrations as distance from the feeder decreased; however, in January, a linear increase ($P < 0.04$) in Mn concentrations occurred as distance from the feeder decreased.

Discussion

Round-bale feeders are a common method of supplying forage to livestock at feeding sites (Taylor et al., 1995). Although hay wastage was not measured in this study, Buskirk et al. (2003) reported DM hay wastage of 6.1% from round-bale ring feeders of similar design to those used in the present study. Because animal activity around these feeders increases, an increase in manure accumulation also occurs. It has been reported by Kronberg et al. (1986) and Johnstone-Wallace and Kennedy (1944) that the total daily fecal output of cattle ranges from 0.5 to 0.75% of BW on a dry-weight basis. On average, this fecal output contains approximately 3.8×10^{10} cfu/g fecal coliforms and 7.2×10^{8} cfu/g fecal *Streptococci* (Moore et al., 1988). Although we did not measure fecal output in relation to the measured distances, we observed greater manure accumulation within 3 m of the feeders then at any other distance, which is supported by data showing increased fecal bacteria concentrations and increases of nutrients in soil at this distance from the feeders.

Temperature of the soil is one of the factors that exert the most influence over bacterial survival. Van Donsel et al. (1967) reported that survival of fecal coliforms and fecal *Streptococci* in soil was decreased in summer compared with autumn/winter. A 90% decrease in fecal coliform concentration in the soil occurred within 3.3 and 13.4 d in summer and fall, respectively, whereas 90% mortality was observed in fecal *Streptococci* within 2.7 d in summer and 20.1 d in winter. Although freezing and thawing decrease bacterial concentrations (Calcott et al., 1976; Kibbey et al., 1978), low temperatures seem to result in greater bacterial survival.

Increased OM content of soil can prolong the survival of fecal organisms (Mallman and Litsky, 1951; Tate, 1978). The supply of nutrients and OM in soil affects the survival of bacteria. According to Klein and Casida (1967), a leading reason for enteric bacteria die-off is an inability to adapt to conditions of decreased nutrient availability.

We believe that soil bacteria may have increased from February to April in the present study for two main reasons. First, an accumulation in fecal deposits at the feeding sites would have occurred as the amount of time cattle were present on the sites increased. Second, previous data suggest a greater survival rate for fecal bacteria in higher moisture soil and before the increased summer temperature season that has been shown to decrease fecal bacteria survivability (Van Donsel et al., 1967). Soil moisture can influence bacterial concentrations (Ellis and McCalla, 1978). Increased survival of *Streptococcus faecalis* and *Salmonella typhimurium* was noted as moisture content of the soil increased at different temperatures (Kibbey et al., 1978). The decrease in soil bacterial concentrations observed from May onward may have resulted from warmer, drier conditions that decrease bacterial survival. In addition, no further fecal deposits were added after this time because cattle were removed from the sites. Therefore, the decrease in fecal bacteria from May to July would be a simple function of bacteria die-off.

In March, April, June, and July, concentrations of soil P decreased as distance from the feeder increased, primarily due to elevated concentrations at 3 m. This increase may be due to P excreted in manure, as well as from wasted hay. Interestingly, the soil N concentration at 3 m from the feeder was least in April, the last month when animals were at feeders, and greatest in June and July, 2 to 3 mo after animals were removed. The authors cannot explain why an increase was observed after cattle were removed from the sites.

Although all feeding sites in this study were located in areas not previously used for feeding, concentrations of S, K, Ca, Fe, and Mn varied due to sampling distance from feeders when evaluated in January, which was before feeding was initiated. For all of these nutrients except soil Ca, linear and quadratic increases were noted as distance from the feeders decreased, whereas the soil Ca concentration exhibited the opposite pattern. No other research data concerning the effect of concentrated feeding sights on the majority of the soil nutrients tested in this study were found.

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