Utilizing an electronic feeder to measure individual mineral intake, feeding behavior, and growth performance of cow–calf pairs grazing native range[1]

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ABSTRACT: Crossbred Angus cow–calf pairs (n = 28 pairs) at the Central Grasslands Research Extension Center (Streeter, ND) were used to evaluate an electronic feeder to monitor individual mineral intake and feeding behavior and their relationship with growth performance and liver mineral concentrations. Cows and calves were fitted with radio frequency identification ear tags that allowed access to an electronic feeder (SmartFeed system; C-Lock Inc., Rapid City, SD) and were provided ad libitum minerals (Purina Wind and Rain Storm, Land O'Lakes, Inc., Arden Hills, MN). Mineral intake, number of visits, and duration at the feeder were recorded over a 95-d monitoring period while pairs were grazing native range. Liver biopsies were collected from a subset of cows on the final day of monitoring and analyzed for mineral concentrations. Data were analyzed with the GLM procedure in SAS for mineral intake and feeding behavior with age class (cows vs. calves), intake category (high vs. low), and the interaction between class and category in the model. Correlations were calculated among cow feeding behavior and calf intake and growth performance with the CORR procedure, and a comparison of liver mineral concentrations among cows of high (>90 g/d; average 125.4 g/d) and low (<90 g/d; average 33.5 g/d) mineral intake was performed using the GLM procedure. High-intake calves (>50 g/d; average 72.2 g/d) consumed greater (P < 0.001) amounts of minerals than low-intake calves (<50 g/d; average 22.2 g/d) intake calves. Cows and calves attended the mineral feeder a similar (P = 0.71) proportion of the days during the experiment (overall mean of 20%, or once every 5 d). On days calves visited the feeder, they consumed less (P < 0.01) minerals than cows (222 ± 27 vs. 356 ± 26 g/d, respectively). Over the grazing period, calves gained 1.17 ± 0.02 kg/d, whereas cows lost 0.35 ± 0.02 kg/d. Calf mineral intake was correlated with cow duration at the mineral feeder (r = 0.403, P = 0.05). Cows with high mineral intake had greater (P < 0.01) concentrations of Se (2.92 vs. 2.41 ug/g), Cu (247 vs. 116 ug/g), and Co (0.51 vs. 0.27 ug/g) compared with low mineral intake cows, but liver concentrations of Fe, Zn, Mo, and Mn did not differ (P ≥ 0.22). We were able to successfully monitor individual mineral intake and feeding behavior with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of minerals in the liver.

Key words: cow–calf, grazing, intake, mineral

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INTRODUCTION

Mineral requirements of grazing cattle are not always satisfied by forages (McDowell, 1996); thus, mineral supplementation is often necessary to optimize animal health and performance (NASEM, 2016). An issue with providing mineral supplements to cattle, however, is the high degree of intake variability associated with free-choice mineral supplements (Cockwill et al., 2000; Greene, 2000). Mineral intake variability is influenced by season, individual animal requirements, animal preference, availability of fresh minerals, mineral palatability, physical form of minerals, salt content of water, mineral delivery method, soil fertility and forage type, forage availability, animal social interactions, and likely other unknown factors (Bowman and Sowell, 1997; McDowell, 2003).

Providing free-choice mineral supplements to pasture-based cattle does not allow the measurement of individual animal mineral intake; as a result, mineral intake is measured on a group basis. The measurement of individual animals' mineral supplement intake allows specific animal responses to be evaluated. Individual animal intake of free-choice minerals is often variable due to the small amounts consumed (Tait and Fisher, 1996). The use of electronic monitoring systems in the beef industry has been limited to systems primarily used in research settings to examine the effects on feed intake in relation to cattle growth performance (Islas et al., 2014), daily intake of salt-limited supplements (Reuter et al., 2017), health status (Wolfger et al., 2015), or animal movement in extensive pasture settings (Schauer et al., 2005). These technologies could be adapted easily for use in beef cattle production systems to monitor activity, feeding, or drinking behavior or as tools for monitoring inventories in intensive or extensive production systems. Moreover, these technologies could be applied to target specific cow or calf supplementation strategies in pasture settings. Therefore, our objective was to evaluate an electronic feeder to monitor individual cow and calf mineral intake and feeding behavior and their relationship with growth performance and concentrations of minerals in the liver.

MATERIALS AND METHODS

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University (A17064).

Study Area

Research was conducted at the Central Grasslands Research Extension Center, located near Streeter, ND, from May 22, 2017 to September 27, 2017. This area is characterized by a continental climate with warm summers and cold winters with a majority (72%) of precipitation occurring between May and September (Limb et al., 2018). August is the warmest month with a mean temperature of 18.6 °C and January is the coldest month with an average low temperature of −15.3 °C (Fig. 1; NDAWN, 2017).

The pasture was 62 ha with a stocking rate of 2.1 animal unit months/ha. The vegetation is classified as mixed-grass prairie dominated by western wheatgrass (*Pascopyrum smithii* [Rydb.] Á.

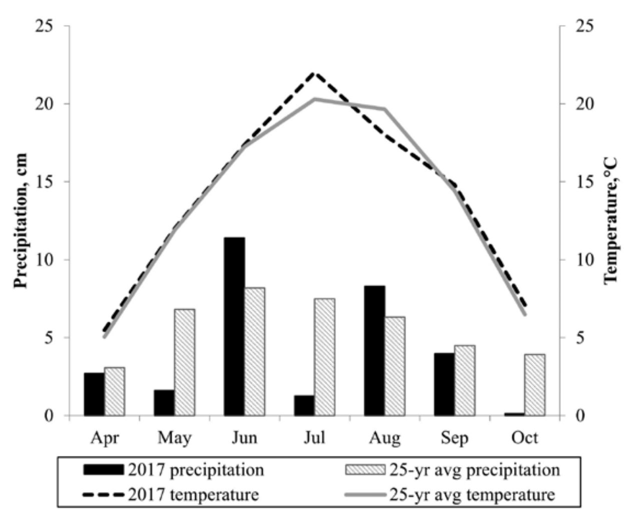

Figure 1. Temperature and precipitation data from April to October 2017 compared with 25-yr average. Data from North Dakota Agricultural Weather Network Station located in Streeter, ND (NDAWN, 2017).

Löve), green needlegrass (*Nassella viridula* [Trin.] Barkworth), and blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths). Other important species present that are important drivers in biodiversity changes in the region include sedges (*Carex* spp.), prairie junegrass (*Koeleria macrantha* [Ledeb.] Schult.), sages (*Artemisia* spp.), and goldenrods (*Solidago* spp.), Kentucky bluegrass (*Poa pratensis* L.) a nonnative grass, and western snowberry (*Symphoricarpos occidentalis* Hook.) a native shrub (Limb et al., 2018).

Electronic Feeder Device

The SmartFeed system (C-Lock, Inc., Rapid City, SD) was used to deliver mineral supplement and measure intake. The system features a stainless-steel feed bin suspended on two load cells, a radio frequency identification (RFID) tag reader and antenna, an adjustable framework to allow access to one animal at a time, and a data acquisition system that records RFID tags and feed bin weights (Reuter et al., 2017). The electronic feeder was fastened securely to the fence line to allow animal access to the feeder and restrict access to electrical components and solar power source. The mineral feeder was located down the fence line in a corner of the pasture 0.2 km away from the water source. The feeder was covered with a plywood shell to protect the feed bin and equipment from wind and rain. Mineral disappearance in the feeder was monitored visually and through the online portal where intake and monitoring of the device were done remotely.

Animal Measurements

Twenty-eight crossbred Angus based primiparous cows [initial body weight (BW) = 586 ± 52 kg] and their suckling calves (initial BW 113 ± 19 kg; 66 ± 8 d of age) were used to evaluate an electronic feeder to monitor mineral intake and feeding behavior and their relationship with growth performance and concentrations of minerals in the liver. The mean value of consecutive day weights of cows and calves were used as initial and final BWs, with single-day BWs collected at 28-d intervals. Cows and calves were fitted with RFID ear tags that allowed access to the electronic feeder, which contained free-choice loose minerals (Purina Wind and Rain Storm, Land O'Lakes, Inc., Arden Hills, MN; Table 1).

Table 1. Composition of mineral supplement consumed by cow–calf pairs grazing native range; company guaranteed analysis[a]

Item	Min	Max
Minerals		
Ca, %	13.5	16.2
P, %	7.5	–
NaCl, %	18.0	21.6
Mg, %	1.0	–
K, %	1.0	–
Mn, mg/kg	3,600	–
Co, mg/kg	12	–
Cu, mg/kg	1,200	–
I, mg/kg	60	–
Se, mg/kg	27	–
Zn, mg/kg	3,600	–
Vitamins, IU/kg		
Vitamin A	661,500	–
Vitamin D	66,150	–
Vitamin E	661.5	–

[a]Purina Wind and Rain Storm Mineral (Land O'Lakes, Inc., Arden Hills, MN). Ingredients: dicalcium phosphate, monocalcium phosphate, calcium carbonate, salt, processed grain byproducts, vegetable fat, plant protein products, potassium chloride, magnesium oxide, natural and artificial flavors, calcium lignin sulfonate, ethoxyquin (a preservative), manganese sulfate, zinc sulfate, basic copper chloride, ethylenediamine dihydroiodide, cobalt carbonate, vitamin A supplement (proprietary), vitamin E supplement (proprietary), and vitamin D3 supplement (proprietary).

The SmartFeed unit was set in training mode (lowest locked setting to allow for ad libitum access to the feeder) and training cattle to the feeders started from initial pasture turn out (May 22, 2017) to June 22, 2017. Mineral intake, number of visits, time of visits, and duration at the feeder were recorded continuously during a 95-d monitoring period while pairs were grazing native range from June 23, 2017 to September 27, 2017. Daily mineral intake was calculated as the sum of individual feeding events in each 24-h period and overall mineral intake was the sum of all feeding events during the 95-d monitoring period. The mean value for overall intake was used as an inflection point to categorize cattle into mineral intake groups. Cows and calves were categorized into one of two mineral intake classifications: high (>90 or >50 g/d for cows and calves, respectively) and low (<90 or <50 g/d for cows and calves, respectively) mineral intake during the 95-d monitoring period.

Liver Sample Collection and Analysis

Samples of liver were collected on day 95 via biopsy from a subset of cows (n = 18) with the greatest and least attendance at the mineral feeder throughout the grazing period. Cows were restrained in a squeeze chute, and the hair between the 10th and 12th ribs was clipped with size 40 blades (Oster; Sunbeam Products Inc., Boca Raton, FL). Liver biopsy samples (approximately 20 mg) were collected using the method of Engle and Spears (2000) with the modifications that all heifers were given 3 mL Lidocaine Injectable-2% (MWI, Boise, ID) with 1.5 mL subcutaneously and 1.5 mL into the intercostal muscles at the target biopsy site. An imaginary line is drawn from the tuber coxae (hook) to the elbow. At the intersection with a line drawn horizontally from the greater trochanter, a stab incision was then made between the 10th intercostal space. A core sample of the liver was taken via the Tru-Cut biopsy trochar (14 g; Merit Medical, South Jordan, UT). The liver sample was blotted dry on ashless filter paper (Whatman 541 Hardened Ashless Filter Papers, GE Healthcare Bio-Sciences, Pittsburg, PA) and then stored in tubes designed for trace mineral analysis (potassium Ethylenediaminetetraacetic acid; Becton Dickinson Co., Franklin Lakes, NJ) and stored at −20 °C until further analysis. After obtaining liver biopsies, a staple (Disposable Skin Staple 35 Wide; Amerisource Bergen, Chesterbrook, PA) and topical antibiotic (Aluspray; Neogen Animal Safety, Lexington, KY) was applied to the surgical site and an injectable Nonsteroidal Anti-inflammatory Drug (Banamine; Merck Animal Health, Madison, NJ) was given intravenously at 1.1 mg/kg of BW. Liver samples were sent to the Veterinary Diagnostic Laboratory at Michigan State University and were evaluated for concentrations of minerals using inductively coupled plasma mass spectrometry.

Forage Collection and Analysis

Forage samples were obtained every 2 wk from 10 different locations in the pasture in a diagonal line across the pasture. The forage samples were hand clipped to a height of 3.75 cm above ground (Undi et al., 2008). Forage samples were dried in a forced-air oven at 60 °C for at least 48 h and then ground to pass through a 2-mm screen using a Wiley mill (Arthur H. Thomas, Philadelphia, PA). Clipped forage samples for each location reported herein are composite over all locations within the representative sampling date. Forage samples were analyzed at the North Dakota State University Nutrition Laboratory for dry matter (DM), crude protein (CP), ash, N (Kjehldahl method), Ca, P, and ether extract (EE) by standard procedures (AOAC, 1990). Multiplying N by 6.25 determined CP calculation. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations were determined by the modified method of Van Soest et al. (1991) using a fiber analyzer (Ankom Technology Corp., Fairport, NY). Samples were also analyzed for Cu, Zn, Co, Mo, Fe, S, and Se using inductively coupled plasma optical emission spectroscopy by the Veterinary Diagnostic Laboratory at Michigan State University.

Statistical Analysis

Data were analyzed using the GLM procedure of SAS (SAS 9.4; SAS Inst. Inc., Cary, NC) with mineral intake and feeding behavior compared among cows and calves. Mineral intake, feeding behavior, and performance were analyzed by age class (cows vs. calves), intake category (high vs. low), and the interaction between class and category. Correlations were generated among cows and calves with the variables cow duration at the feeder, intake, and BW and calf average daily gain, intake, and duration at the feeder using the CORR procedure of SAS. Comparisons of liver mineral concentrations among cows of high (>90 g/d) and low (<90 g/d) mineral intake were analyzed with PROC GLM. For all analyses, significance was set at $P \le 0.05$.

RESULTS AND DISCUSSION

Mineral Intake and Feeding Behavior

Over the duration of the 95-d grazing period, cows consumed more ($P < 0.001$; Table 2) minerals than calves. An age class × mineral intake category interaction ($P = 0.005$) was detected for intake over the 95-d monitoring period, with high-intake cows having greater mineral consumption (125.4 g/d; $P < 0.001$) compared with high-intake calves (72.2 g/d), which were greater ($P < 0.001$) than low-intake cows and calves (33.5 vs. 22.2 g/d, respectively). Generally, cattle mineral formulations are designed to fall within the targeted intake of between 56 and 114 g/d per animal for free-choice mineral supplementation (Greene, 2000). Variability in feeder attendance and daily mineral intake by individual cattle utilizing other electronic feeders have been reported by multiple research groups (Cockwill et al., 2000; Manzano et al, 2012; Patterson et al., 2013). Furthermore, Patterson et al. (2013) evaluated cows and their calves using a Calan gate feeder system and provided three different supplemental sources of Se

Table 2. Mineral intake and feeding behavior of grazing cow–calf pairs on native range utilizing an electronic feeder

	Calves[a]		Cows[b]			*P*-value		
Item	High	Low	High	Low	SEM	Age class	Intake category	Class × Category
95 d intake[c], g/d	72.2[b]	22.2[c]	125.4[a]	33.5[c]	5.7	<0.001	<0.001	0.005
Days eating, %	27.5	14.5	27.5	14.5	1.4	0.83	<0.001	0.64
Intake[d], g/d	300.1[b]	161.2[c]	461.8[a]	242.5[b]	28.1	<0.001	<0.001	0.005
Time[e], min	147.3	57.2	118.4	39.4	9.3	0.02	<0.001	0.56
Eating rate, g/min	49.4	39.2	106.6	74.8	7.3	<0.001	<0.006	0.14

[abc]Means within row lacking common superscript differ ($P < 0.05$).

[a]Calf divergent mineral intake classified calves as high (>50 g/d) or low (<50 g/d) mineral intake.

[b]Cow divergent mineral intake classified cows as high (>90 g/d) or low (<90 g/d) mineral intake.

[c]Represents average daily intake over the course of the 95-d monitoring period.

[d]Represents daily intake on the days cows and calves attended the electronic feeder.

[e]Time represents the total time in minutes spent at the feeder over the course of the 95-d monitoring period.

during a year-long production regimen and also reported variability with intakes ranging from 27.9 to 97.3 g/d with a mean mineral consumption of 54 g/d. However, calf intake was not evaluated in Patterson et al. (2013). Compared to utilizing electronic feeders, Pehrson et al. (1999) provided mineral supplement in a wooden box to grazing cows for an 80-d period and calculated the mean daily supplement consumption by dividing the total amount of feed by the number of animals consuming it, with the assumption that calves did not consume any significant amount. Thus, Pehrson et al. (1999) estimated that the daily consumption for Se yeast mineral supplement was 110 g/cow, whereas cows supplemented with selenite consumed 107 g/cow. Our group was able to use the SmartFeed system to evaluate the mineral intake of cow–calf pairs on pasture and record individual intakes of calves that the aforementioned groups were unable to evaluate. The observation of high-intake calves consuming more minerals than low-intake cows reveals the importance of considering calf intake when making decisions about the amount of supplement to be offered or interpreting mineral disappearance in pastures where cow–calf pairs are grazing.

No class × category interactions ($P > 0.14$) were present in the proportion of days cattle consumed mineral, time spent at the feeder, or eating rate (Table 2). Furthermore, no differences were observed for age class for the proportion of days attending the feeder ($P = 0.83$); however, high-intake cattle spent a greater proportion of days consuming minerals compared to low-intake cattle ($P < 0.001$). Overall, calves spent more time at the feeder compared to cows ($P < 0.001$), and high-intake cows and calves spent more time at the mineral feeder than their low-intake counterparts ($P = 0.02$). The reduced intake of calves combined with a longer time at the feeder resulted in a slower overall rate of mineral consumption for calves compared with cows ($P < 0.0001$), and high-intake animals ate faster ($P < 0.006$) than low-intake animals. It is important to note that both classes of cattle attended the mineral feeders for a similar ($P = 0.71$) proportion of days during the experiment (overall mean of only 20% or once every 5 days). Interestingly though, mean intake values for cows and calves over the course of the experiment did not meet manufacturers' feeding recommendation (113.4 g) for the minerals used because the cattle did not visit the feeders every day but the mineral intake of both cows and calves exceeded the manufacturers feeding recommendation on days they did visit the feeders.

Mineral intake on the days cows and calves visited the mineral feeders was impacted by an age class × intake category interactions ($P = 0.005$), with high-intake cows consuming more ($P < 0.001$) minerals (461.8 g/d) than low-intake cows (242.5 g/d) and high-intake calves (300.1 g/d), which consumed more ($P < 0.001$) than low-intake calves (161.2 g/d). Cockwill et al. (2000) reported high variability of mineral intake over a 6-d grazing period with individual intakes among cows and calves ranging from 0 to 974 and 0 to 181 g/d, respectively. Unfortunately, little field data exist for individual free-choice mineral intake by cows and calves managed under forage-based cow–calf regimens (Patterson et al., 2013). The current experiment offers a glimpse of mineral intake variability over a 3-month period in cows and calves grazing the native range.

With the proportion of days during the experiment that cattle were consuming minerals, the location of the mineral feeder and grazing behavior may explain the variation in intake over the grazing period. It is probable that such distances from the water source could also alter patterns of electronic feeder attendance. Likewise, Smith et al. (2016) reported that individual steers visited a mineral feeder an average of 44.3% of the days monitored (90-d monitoring period) when the mineral feeder was in immediate proximity to the water source. In the current experiment, we did not implement a training period before pasture turnout; thus, the novelty of the feeder could have contributed to the neophobic behavior of new feeding devices or feeds (Bowman and Sowell, 1997). However, the training period utilized in the experiment should have been sufficient to overcome the neophobic behavior. Probably, the inability to move the feeder away from the corner of the pasture and closer to the water or increase cattle traffic influenced the proportion of days the cattle attended the feeder.

Cow and Calf Performance

There were no class by intake category interactions ($P \geq 0.53$; Table 3) for cow and calf BWs over the course of the monitoring period (Table 3). Final BW for cows and calves were 568 ± 53 kg and 245 ± 28 kg, respectively. Suckling calf weight increased over the grazing period and gained 1.39 ± 0.04 kg/d, whereas cows lost 0.19 ± 0.04 kg/d as the season advanced, which was likely due to declining forage nutrient content combined with demands of lactation. The variation in nutrient requirements that come from changes in forage nutritive value and availability results in cows increasing and decreasing in BW and body condition in a cyclic pattern throughout the production year (NASEM, 2016). Additionally, primiparous cows require additional nutrient requirements for their own growth, meeting nutrient requirements for lactation to support an existing offspring, and overall maintenance (Short et al., 1990; Meek et al., 1999; NASEM, 2016), which makes it hard to gain weight.

The amount of time cows spent at the mineral feeder was positively correlated with cow mineral intake ($r = 0.923$; $P < 0.01$; Table 4). Additionally, the amount of time calves spent at the feeder was positively correlated with calf mineral intake ($r = 0.948$; $P < 0.01$). The time cows spent at the feeder was also positively correlated with calf mineral intake ($r = 0.403$; $P = 0.05$). Similar findings have been reported with inexperienced sheep increasing supplement intake in the presence of more experienced sheep (Bowman and Sowell, 1997). Furthermore, cow starting BW was negatively correlated with the duration the calf spent at the feeder and calf intake ($r = -0.631$ and -0.553, respectively; $P < 0.01$). This could suggest that as the grazing season progressed, the cow's milk production was declining because of the normal lactation curve and the decreasing quality of the forages available. Or it could suggest that heavier cows produced more milk and, therefore, calves from heavier cows consumed less minerals at the feeders. It has been reported that suckling calves increase forage intake to compensate for reduced milk intake (Boggs et al., 1980). Therefore, calves in the current study could be responding to variation in cow milk production

Table 3. Performance of grazing cow–calf pairs on native range utilizing an electronic feeder

	Calves[a]		Cows[b]			*P*-value		
Item	High	Low	High	Low	SEM	Age class	Intake category	Class × Category
BW, kg								
Pasture turnout[c]	92.3	89.9	607.9	597.2	10.8	<0.0001	0.549	0.709
June 5[d]	114.7	115.3	588.9	581.7	10.9	<0.0001	0.766	0.720
July 3	147.8	149.2	585.0	577.9	11.3	<0.0001	0.800	0.707
July 31	182.8	182.8	587.6	577.7	11.1	<0.0001	0.660	0.656
Aug 28	217.5	215.1	581.8	565.9	10.7	<0.0001	0.393	0.529
Final[e]	249.1	245.6	571.3	563.9	11.7	<0.0001	0.647	0.868
Gain[f], kg	134.4	130.3	−17.7	−17.8	4.02	<0.0001	0.602	0.626
ADG[g], kg/d	1.41	1.37	−0.19	−0.19	0.04	<0.0001	0.602	0.626

[a]Calf divergent mineral intake classified calves as high (>50 g/d) or low (<50 g/d) mineral intake.

[b]Cow divergent mineral intake classified cows as high (>90 g/d) or low (<90 g/d) mineral intake.

[c]Pasture turnout weights are the mean value of consecutive day weights of cows and calves on May 15 and 16, 2017.

[d]June 5 weight is the start weight used for the 95-d monitoring period.

[e]Final BW are the mean value of consecutive day weights of cows and calves on September 25 and 26, 2017.

[f]Gain: the BW gained from start weight to final BW during the 95-d monitoring period.

[g]ADG: average daily gain is weight gained divided by the 95-d monitoring period.

by altering the consumption of available forage and mineral supplementation. However, the milk intake of calves was not evaluated in this study.

Forage Analysis

Forage nutrient content appeared to decrease over the course of the mineral intake grazing period (Table 5) as noted with decreasing CP and increasing values for NDF and ADF. A decrease in the forage nutritive value is typical in the diets of grazing cattle during the advancing season (Bedell, 1971; Schauer et al., 2004; Cline et al., 2009). The nutrient availability of grazed forages fluctuates by environmental conditions, forage species, soil type, and stage of maturity (NASEM, 2016). Recommended allowance for Se, Fe, Cu, Zn, and Mn are 0.10, 50, 10, 30, and 40 mg/kg dietary DM, respectively (NASEM, 2016). Selenium in forage can range widely within and between different types of feedstuffs (Suttle, 2010). However, pasture Se concentrations were below detectable levels for the assay (0.10 mg/kg) and were thus deficient. Iron in pastures has been shown to have seasonal fluctuations with peaks in spring and autumn (Suttle, 2010), where our current forage Fe concentrations were adequate over the course of the grazing season. According to Corah and Dargatz (1996), forage Fe is within adequate levels at 50–200 mg/kg. Concentrations of Cu in forage were marginal to deficient (4–7 vs. <4 mg/kg, respectively; Corah and Dargatz, 1996). Furthermore, NASEM (2016) recommends concentrations of Cu to be 10 mg/kg in beef cattle diets. According to Corah and Dargatz (1996), concentrations of Zn were deficient (<20 mg/kg) over the course of the grazing period, whereas, according to Corah and Dargatz (1996), Mo, Co, and Mn were adequate (<1, 0.1–0.25, >40 mg/kg, respectively). Grings et al. (1996) found that Mo

Table 4. Correlations among performance and mineral feeding behavior of cows and calves while grazing native range

	Cow duration[a]	Cow BW[b]	Cow intake	Calf ADG	Calf duration[c]	Calf intake
Cow duration	–	0.041 (P = 0.84)	0.923 (P < 0.01)	−0.135 (P = 0.50)	0.306 (P = 0.13)	0.403 (P = 0.05)
Cow BW		–	0.048 (P = 0.81)	0.204 (P = 0.23)	−0.631 (P < 0.01)	−0.553 (P < 0.01)
Cow intake			–	−0.134 (P = 0.51)	0.185 (P = 0.36)	0.279 (P = 0.19)
Calf ADG				–	−0.166 (P = 0.42)	−0.212 (P = 0.32)
Calf duration					–	0.948 (P < 0.01)
Calf intake						–

[a]Total amount of time (minutes) cows spent at the mineral feeder.

[b]Cow BW at the start of the 95-d monitoring period.

[c]Total amount of time (minutes) calves spent at the mineral feeder.

Table 5. Forage analysis of pasture grazed by cow–calf pairs from May to September 2017[a]

	Grazing period[b]				
Item	May	June	July	August	September
TDN[c]	63.9	63.25	62.05	61.45	60.23
CP, %	9.08	8.30	6.47	5.82	6.67
Ash	10.27	9.42	9.31	9.79	10.09
NDF, %	58.98	60.88	62.48	62.04	65.22
ADF, %	31.65	32.46	33.97	34.75	36.27
Ca, %	0.36	0.37	0.40	0.40	0.44
P, %	0.19	0.16	0.14	0.12	0.14
S, %	0.1259	0.1285	0.1107	0.1160	0.1257
Fe, mg/kg	144.0	90.5	92.5	77.5	193.7
Cu, mg/kg	4.40	4.20	3.20	2.95	3.70
Zn, mg/kg	18.30	17.85	14.35	15.10	17.23
Mo, mg/kg	1.20	0.95	1.30	1.25	1.37
Mn, mg/kg	86.3	67.3	72.1	84.4	99.8

[a]Clipped forage samples from 10 different locations reported herein are composite over all locations within the representative sampling dates.

[b]Values presented are mean values of the representative sampling dates within the given month: May (n = 1), June (n = 2), July (n = 2), August (n = 2), and September (n = 3).

[c]Total Digestible Nutrients = 88.9 – (0.79 × ADF%) (Lardy, 2018).

content ranged from 1 to 2 mg/kg in forages from the Northern Great Plains, which our pastures fall within this similar range. Taken together, the analyzed mineral composition of the pastures revealed that providing supplements containing Cu and Zn was warranted.

Liver Mineral Concentrations

Cows with high mineral intake had greater ($P < 0.01$) liver concentrations of Se, Cu, and Co compared with low mineral intake cows, but liver concentrations of Fe, Zn, Mo, and Mn did not differ ($P \geq 0.22$; Table 6) among cows in respective mineral intake categories. Selenium concentrations in the liver for high cows were classified as high adequate (>2.50 µg/g DM; Kincaid, 2000) and low mineral intake cows were classified as adequate (1.25 to 2.50 µg/g DM; Kincaid, 2000). For liver concentrations of Cu, low cows would be just under the threshold of 125 µg/g DM considered adequate by Kincaid (2000) but still considered normal according to Radostits et al. (>100 µg/g DM; Radostits et al. 2007). Cows in the high and low mineral intake categories both had liver Co above the satisfactory threshold of 0.08 to 0.12 µg/g DM set forth by McNaught (1948), which high and low cows were above satisfactory levels. According to Kincaid (2000), liver mineral concentrations for Fe, Zn, Mo, and Mn are considered adequate for high and low groups. Overall, cows in the high mineral intake groups had greater concentrations of Se, Cu, and Co, indicating more available bodily stores of minerals for their own physiological and metabolic processes and for those of their gestating offspring. In addition, though most minerals evaluated were in adequate ranges in the low-intake cows, Cu status was near the threshold for marginal status.

Table 6. Liver mineral concentrations of cows with divergent mineral intake from an electronic feeder

	Intake category[a]			
Item, µg/g	High	Low	SE	*P*-value
n	9	9		
Se	2.92[a]	2.41[b]	0.10	0.003
Fe	202.3	220.0	21.9	0.576
Cu	247.0[a]	115.6[b]	21.6	0.0005
Zn	110.7	118.7	16.5	0.737
Mo	3.98	3.75	0.29	0.595
Mn	9.74	8.84	0.50	0.217
Co	0.51[a]	0.27[b]	0.05	0.002

[ab]Means within row lacking common superscript differ ($P < 0.05$).

[a]Cow divergent mineral intake classified cows as high (>90 g/d) or low (< 90 g/d) mineral intake.

CONCLUSIONS

The use of an electronic feeder in the pasture enabled the measurement of individual ad libitum intake of free-choice minerals by individual cows and calves. In this system, all cow–calf pairs had equal ad libitum access to native range forage and access to minerals. Overall, calves spent more time at the feeder compared to cows. Additionally, high-intake cows and calves spent more time at the mineral feeder than their low-intake counterparts. Furthermore, we noted greater concentrations of Se, Cu, and Co in livers of high-intake cows compared to low-intake cows. In conclusion, we were able to successfully monitor mineral intake and feeding behavior with the electronic feeder evaluated, and the divergence in mineral intake observed with the feeder was corroborated by concentrations of minerals in the liver.

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