Utilizing an Electronic Feeder to Measure Individual Mineral Intake, Feeding Behavior, and Growth Performance of Cow-calf Pairs Grazing Native Range

Kacie L. McCarthy*, Michael Undi#, Stephanie Becker# and Carl R. Dahlen*[2]
*Department of Animal Sciences, North Dakota State University, Fargo, ND 58102
#Central Grasslands Research Extension Center, Streeter, ND 58483

Summary

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. 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 with the GLM procedure. HIGH intake calves (>50 g/d; average 72.2 g/d) consumed greater ($P < 0.001$) amounts of mineral 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 days). On days calves visited the feeder, they consumed less ($P < 0.01$) mineral 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 ($P \geq 0.22$). 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 mineral in the liver.

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). Supplementing mineral to cattle grazing poor-quality range vegetation can improve forage utilization and animal performance (Köster et al., 1996; Caton and Dhuyvetter, 1997). An issue with providing mineral supplements to cattle; however, is the high degree of intake variability associated with free choice mineral supplements (Greene, 2000; Cockwill et al., 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 measurement of individual animal mineral intake; as a result, mineral intake is measured on a group basis. Measurement of individual animals' mineral supplement intake allows specific animal responses to be evaluated. 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, we could apply these technologies 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 mineral 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 (Figure 1; NDAWN, 2017).

The pasture was 62 ha with a stocking rate of 2.1 Animal Unit Months (AUMs)/ha. The vegetation is classified as mixed-grass prairie dominated by western wheatgrass (*Pascopyrum smithii* [Rydb.] À. Löve), green needlegrass (*Nassella viridula* [Trin.] Barkworth) and blue grama (*Bouteloua graciles* [Willd. ex Kunth] Lag. ex Griffiths). Other important species include sedges (*Carex* spp.), prairie Junegrass (*Koeleria macrantha* [Ledeb.] Schult.), sages (*Artemisia* spp.), and goldenrods (*Solidago* spp.), Kentucky bluegrass (*Poa pratensis* L.) a non-native grass, and western snowberry (*Symphoricarpos occidentalis* Hook.) a native shrub, are important drivers in biodiversity changes in the region (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 (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 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 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 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 mineral in the liver. The mean value of consecutive day weights of cows and calves were used as initial and final body weights, with single day body weights collected at 28 d intervals. Body condition score was assessed on cows at the initiation and completion of the 95-d monitoring period. Cows and calves were fitted with RFID ear tags that allowed access to the electronic feeder, which contained free choice loose mineral (Purina Wind and Rain Storm, Land O'Lakes, Inc., Arden Hills, MN; Table 1).

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. 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 median 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 d 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 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 an intradermal 3 mL injection of Lidocaine Injectable-2% (MWI, Boise, ID) 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 liver was taken via the Tru-Cut biopsy trochar (14 g; Merit Medical, South Jordan, UT). The liver sample was placed 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 EDTA; 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 NSAID (Banamine; Merck Animal Health, Madison, NJ) was given intravenously at 1.1 mg/kg of body weight. 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 (ICP-MS).

Forage Collection and Analysis
Forage samples were obtained every two weeks from ten 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. 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 crude protein 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 (ICP-OES) 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 and feeding behavior 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 ADG, intake, 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 analysis, significance was set at $P \leq 0.05$.

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) mineral 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; $P < 0.001$) compared with HIGH intake calves (72.2 g), which were greater ($P < 0.001$) than LOW intake cows and calves (33.5 g vs. 22.2 g, 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). Research groups have reported on feeder attendance and daily mineral intake by individual cattle utilizing other electronic feeders (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 3 different supplemental sources of Se 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 fed by the number of animals consuming it, with the assumption that calves did not consume any significant amount. Thus, Pehrson et al. (1999) estimated daily consumption for Se yeast mineral supplement was 110 g/cow; whereas, cows supplemented with selenite consumed 107 g/cow. Although Pehrson et al. (1999) assumed calves did not consume any significant amount, our results show that calves in fact can consume more than some LOW consuming cows and may need to be considered when providing mineral supplement to a group on pasture. Nevertheless, our group was able to use the SmartFeed system to evaluate mineral intake of cow-calf pairs on pasture and record individual intakes of calves that the aforementioned groups were unable to evaluate.

No class × category interactions ($P > 0.14$) were present in the proportion of days cattle consumed mineral, time spent at the feeder, and eating rate.

Further, no differences were observed for age class (*P* = 0.83); however, HIGH intake cattle spent a greater proportion of days consuming mineral compared to LOW intake cattle (*P* < 0.001). Overall, calves spent more time at the feeder compared to cows (*P* < 0.001). With HIGH intake cows and calves spending more time at the mineral feeder than their LOW intake counterparts (*P* = 0.02). Calves spent more time at the feeders and consumed less mineral that resulted in an overall slower eating rate. However, cows ate faster (*P* < 0.001) than calves 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 similar (*P* = 0.71) proportion of days during the experiment (overall mean of only 20 percent, 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 mineral used, because cattle did not visit feeders every day but the mineral intake of both cows and calves exceeded the manufacturers feeding recommendation on days they did visit the feeders.

On the days cows and calves visited the mineral feeders, HIGH intake cows consumed more (*P* < 0.001) mineral (461.8 kg/d) compared to LOW intake cows 242.5 kg/d and consumed more mineral than calves. Further, HIGH intake calves consumed more mineral (300.1 kg/d) than LOW intake calves (161.2 kg/d; *P* < 0.001). In addition, HIGH intake calves consumed more mineral than LOW intake cows (*P* = 0.005). 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 offers a glimpse of mineral intake variability over a 3-month period in cows and calves grazing native range.

With the proportion of days during the experiment that cattle were consuming mineral, location of the mineral feeder and grazing behavior may explain 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. Therefore, additional observations of cattle movements would need to be made to better understand frequency of attendance at the mineral feeder.

Cow and calf performance

Final body weight for cows and calves were 568 ± 53 kg and 245 ± 28 kg, respectively. Suckling calf weight increased over the grazing period and gained 1.17 ± 0.02 kg/d.; whereas, cows lost 0.35 ± 0.02 kg/d as 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 body weight and body condition in a cyclic pattern throughout the production year (NASEM, 2016). Additionally, primiparous cows require additional nutrient requirements for their own growth and 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.

Amount of time cows spent at the mineral feeder was positively correlated with cow mineral intake (r = 0.923; *P* < 0.01; Table 3). 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 body weight was negatively correlated with the duration the calf spent at the feeder and calf intake (r = -0.631 and -0.553, respectively; $P < 0.01$; Table 4). 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 mineral 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 accounting for the variation in cow milk production and in turn, compensating with available forage and mineral supplementation. However, 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. A decrease in the forage nutritive value is typical in 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, the current pasture Se concentrations are below detectable levels for the assay. Iron in pastures has been shown to have seasonal fluctuations with peaks in spring and autumn (Suttle, 2010), where our current forage Fe concentrations are adequate over the course of the grazing season. According to Corah and Dargatz (1996), forage Fe is within adequate levels at 50 to 200 mg/kg. Concentrations of Cu in forage were marginal to deficient (4 to 7 vs. < 4 mg/kg, respectively; Corah and Dargatz, 1996). 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 to 0.25, > 40 mg/kg, respectively). Grings et al. (1996) found that Mo content ranged from 1 to 2 mg/kg in forages from the Northern Great Plains, which our pastures fall within this similar range.

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 adequate (1.25 to 2.50 µg/g DM; Kincaid, 2000). Adequate liver Cu concentrations are defined as 125 to 600 µg/g DM (Kincaid, 2000) or normal > 100 µg/g DM (Radostits et al., 2007). Therefore, HIGH and LOW cows would be considered adequate to normal for liver Cu concentrations. Liver Co levels at 0.08 to 0.12 µg/g DM or more indicate satisfactory Co status (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 and

LOW mineral intake groups had adequate liver mineral concentrations.

Conclusions

The use of an electronic feeder in the pasture enabled the measurement of individual ad libitum intake of free-choice mineral by individual cows and calves. In this system, all cow-calf pairs had equal ad libitum access to native range forage and access to mineral. 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 mineral in the liver.

Literature Cited

AOAC. 1990. Official methods of analysis. 15th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Bedell, T. E. 1971. Nutritive Value of Forage and Diets of Sheep and Cattle from Oregon Subclover-Grass Mixtures. J. Range Manage. 24:125-133. doi: 10.2307/3896521

Boggs, D. L., E. F. Smith, R. R. Schalles, B. E. Brent, L. R. Corah, and R. J. Pruitt. 1980. Effects of Milk and Forage Intake on Calf Performance. J. Anim. Sci. 51:550-553. doi: 10.2527/jas1980.513550x

Bowman, J. G. P., and B. F. Sowell. 1997. Delivery method and supplement consumption by grazing ruminants: a review. J. Anim. Sci. 75:543-550. doi: 10.2527/1997.752543x

Caton, J. S., and D. V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. J. Anim. Sci. 75:533-542. doi: 10.2527/1997.752533x

Cline, H. J., B. W. Neville, G. P. Lardy, and J. S. Caton. 2009. Influence of advancing season on dietary composition, intake, site of digestion, and microbial efficiency in beef steers grazing a native range in western North Dakota. J. Anim. Sci. 87:375-383. doi: 10.2527/jas.2007-0833

Cockwill, C. L., T. A. McAllister, M. E. Olson, D. N. Milligan, B. J. Ralston, C. Huisma, and R. K. Hand. 2000. Individual intake of mineral and molasses supplements by cows, heifers and calves. Can. J. Anim. Sci. 80:681-690. doi: 10.4141/A99-120

Corah, L. R., and D. Dargatz. 1996. Forage analyses from cow/calf herds in 18 states. Report: Beef cow/calf health and productivity audit. USDA. https://www.aphis.usda.gov/animal_health/nahms/beefcowcalf/downloads/chapa/CHAPA_dr_ForageAnal.pdf (Accessed 1 October 2018.)

Engle, T. E., and J. W. Spears. 2000. Effects of dietary copper concentration and source on performance and copper status of growing and finishing steers. J. Anim. Sci. 78:2446-2451. doi: 10.2527/2000.7892446x

Greene, L. W. 2000. Designing mineral supplementation of forage programs for beef cattle. J. Anim. Sci. 77:1-9. doi: 10.2527/jas2000.00218812007700ES0013x

Grings, E. E., M. R. Haferkamp, R. K. Heitschmidt, and M. G. Karl. 1996. Mineral Dynamics in Forages of the Northern Great Plains. J. Range Manag. 49:234-240. doi: 10.2307/4002884

Islas, A., T. C. Gilbery, R. S. Goulart, C. R. Dahlen, M. L. Bauer, and K. C. Swanson. 2014. Influence of supplementation with corn dried distillers grains plus solubles to growing calves fed medium-quality hay on growth performance and feeding behavior. J. Anim. Sci. 92:705-711. doi: 10.2527/jas.2013-7067

Kincaid, R. L. 2000. Assessment of trace mineral status of ruminants: A review. J. Anim. Sci. 77(Suppl. E):1-10. doi: 10.2527/jas2000.77E-Suppl1x

Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. J. Anim. Sci. 74:2473-2481. doi: 10.2527/1996.74102473x

Lardy, G. P. 2018. Forage Quality series: Forage Nutrition for Ruminants. In: North Dakota State University Extension Publication AS1250. p 1-16. https://www.ag.ndsu.edu/publications/livestock/quality-forage-series-forage-nutrition-for-ruminants/as1250.pdf

Limb, R., T. Hovick, J. Norland, and J. M. Volk. 2018. Grassland plant community spatial patterns driven by herbivory intensity. Agric. Ecosyst. Environ. 257:113-119. doi: 10.1016/j.agee.2018.01.030

Manzano, R. P., P. J. Paterson, M. M. Harbac, and R. O. L. Filho. 2012. The effect of season on supplemental mineral intake and behavior by grazing steers. Prof. Anim. Sci. 28:73-81. doi: 10.15232/S1080-7446(15)30317-X

McDowell, L. R. 1996. Feeding minerals to cattle on pasture. Anim. Feed Sci.Tech. 60:247-271. doi: https://doi.org/10.1016/0377-8401(96)00983-2

McDowell, L. R. 2003. Minerals in Animal and Human Nutrition. 2nd ed. Elsevier, Amsterdam.

McNaught, K. J. 1948. Cobalt, copper and iron in the liver in relation to cobalt deficiency ailment. New. Zeal. J. Sci.Tech., Section A 30:26-43.

Meek, M. S., J. C. Whittier, and N. L. Dalsted. 1999. Estimation of Net Present Value of Beef Females of Various Ages and the Economic Sensitivity of Net Present Value to Changes in Production. Prof. Anim. Sci. 15:46-52. doi: 10.15232/S1080-7446(15)31723-X

NASEM. 2016. Nutrient requirements of beef cattle: Eighth revised edition. National Academies Press, Washington, DC.

NDAWN. 2017. North Dakota Agricultural Weather Network. https://ndawn.ndsu.nodak.edu/ (Accessed August 15 2018).

Patterson, J. D., W. R. Burris, J. A. Boling, and J. C. Matthews. 2013. Individual intake of free-choice mineral mix by grazing beef cows may be less than typical formulation assumptions and form of selenium in mineral mix affects blood Se concentrations of cows and their suckling calves. Biol. Trace Elem. Res. 155:38-48. doi: 10.1007/s12011-013-9768-7

Pehrson, B., K. Ortman, N. Madjid, and U. Trafikowska. 1999. The influence of dietary selenium as selenium yeast or sodium selenite on the concentration of selenium in the milk of Suckler cows and on the selenium status of their calves. J. Anim. Sci. 77:3371-3376. doi: 10.2527/1999.77123371x

Radostits, O. M., C. C. Gay, K. W. Hinchcliff, and P. D. Constable. 2007. Veterinary Medicine: A textbook of the diseases of cattle, horses, sheep, pigs, and goats. Saunders Elsevier.

Reuter, R. R., C. A. Moffet, G. W. Horn, S. Zimmerman, and M. Billars. 2017. Technical Note: Daily variation in intake of a salt-limited supplement by grazing steers. Prof. Anim. Sci. 33:372-377. doi: http://dx.doi.org/10.15232/pas.2016-01577

Schauer, C. S., K. K. Sedivec, M. L. Bauer, W. D. Slanger, and G. P. Lardy. 2004. Self-limiting supplements fed to cattle grazing native mixed-grass prairie in the northern Great Plains. J. Anim. Sci. 82:298-306. doi: 10.2527/2004.821298x

Schauer, C. S., D. W. Bohnert, D. C. Ganskopp, C. J. Richards, and S. J. Falck. 2005. Influence of protein supplementation frequency on cows consuming low-quality forage: performance, grazing behavior, and variation in supplement intake. J Anim. Sci. 83:1715-1725. doi: 10.2527/2005.8371715x

Short, R. E., R. A. Bellows, R. B. Staigmiller, J. G. Berardinelli, and E. E. Custer. 1990. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle2. J. Anim. Sci. 68:799-816. doi: 10.2527/1990.683799x

Smith, S. C., G. A. Highfill, D. E. Cooper, J. A. Smith, and R. P. Wettemann. 2016. Case Study: Frequency of visits to a mineral feeder by steers grazing wheat pasture. Prof. Anim. Sci. 32:106-109. doi: 10.15232/pas.2015-01432

Suttle, N. F. 2010. Mineral Nutrition of Livestock. 4th ed. CAB International, Cambridge, MA.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597. doi: 10.3168/jds.S0022-0302(91)78551-2

Wolfger, B., E. Timsit, E. A. Pajor, N. Cook, H. W. Barkema, and K. Orsel. 2015. Technical note: Accuracy of an ear tag-attached accelerometer to monitor rumination and feeding behavior in feedlot cattle. J. Anim. Sci. 93:3164-3168. doi: 10.2527/jas.2014-8802

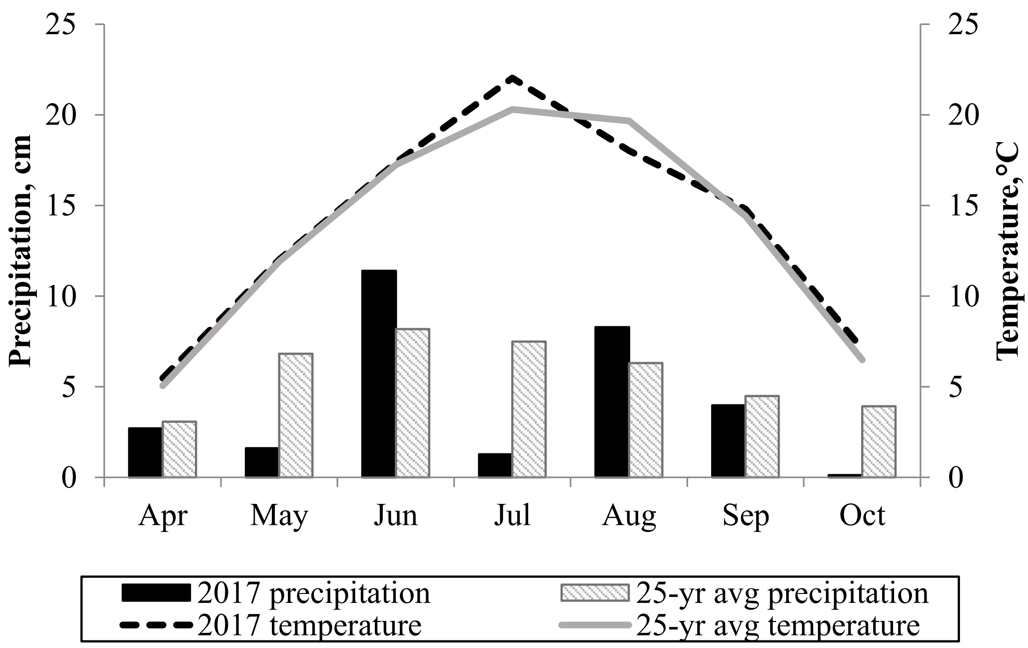

Figure 1. Temperature and precipitation data from April to October 2017 compared with 25-yr average. Data from North Dakota Agricultural Weather Network Station located in Streeter, ND (NDAWN, 2017).

Table 1. Composition of Purina Wind and Rain Storm Mineral (Land O'Lakes, Inc., Arden Hills, MN) with company guaranteed analysis

	%		mg/kg	
Item	min	max	min	max
Minerals[1]				
Ca	13.5	16.2	-	-
P	7.5	-	-	-
NaCl	18.0	21.6	-	-
Mg	1.0	-	-	-
K	1.0	-	-	-
Mn	-	-	3,600	-
Co	-	-	12	-
Cu	-	-	1,200	-
I	-	-	60	--
Se	-	-	27	-
Zn	-	-	3,600	-
	IU per kg			
Vitamins[2]				
Vitamin A	661,500	-	-	-
Vitamin D	66,150	-	-	-
Vitamin E	661.5	-	-	-

[1]Ingredients: Dicalcium Phosphate, Monocalcium Phosphate, Calcium Carbonate, Salt, Processed Grain By-Products, 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 Dihydroioidide, Cobalt Carbonate

[2]Ingredients: Vitamin A Supplement (proprietary), Vitamin E Supplement (proprietary), Vitamin D3 Supplement (proprietary)

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

	Calves[1]		Cows[2]			*P*-Value		
Item	High	Low	High	Low	SEM	Age Class	Intake Category	Class × Category
95 d intake[3], 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[a]	14.5[b]	27.5[a]	14.5[b]	1.4	0.83	< 0.001	0.64
Intake[4], g/d	300.1[b]	161.2[c]	461.8[a]	242.5[b]	28.1	< 0.001	< 0.001	0.005
Time, min	147.3[a]	57.2[c]	118.4[b]	39.4[c]	9.3	0.02	< 0.001	0.56
Eating rate, g/min	49.4[c]	39.2[c]	106.6[a]	74.8[b]	7.3	< 0.001	< 0.006	0.14

[abc]Means within row lacking common superscript differ ($P < 0.05$).
[1]Calf divergent mineral intake classified calves as HIGH (> 50 g/d) or LOW (< 50 g/d) mineral intake.
[2]Cow divergent mineral intake classified cows as HIGH (> 90 g/d) or LOW (< 90 g/d) mineral intake.
[3]Represents average daily intake over the course of the 95-d monitoring period.
[4]Represents daily intake on the day's cows and calves attended the electronic feeder.

Table 3. Correlation coefficient (r) and associated P-values between cow-calf pairs intake and duration at mineral feeder while grazing native range for 95-d monitoring period and utilizing an electronic feeder for mineral intake

	Cow Duration	Cow Intake	Calf Duration	Calf Intake
Cow Duration	——	0.923 ($P < 0.01$)	0.306 ($P = 0.13$)	0.403 ($P = 0.05$)
Cow Intake		——	0.185 ($P = 0.36$)	0.279 ($P = 0.19$)
Calf Duration			——	0.948 ($P < 0.01$)
Calf Intake				——

Table 4. Correlation coefficient (*r*) and associated *P*-values between cow BW and calf performance while grazing native range for 95-d monitoring period and utilizing an electronic feeder for mineral intake

	Cow BW	Cow Intake	Calf ADG	Calf Duration	Calf Intake
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					——

Table 5. Forage analysis of pasture grazed by cow-calf pairs from May to September 2017[1].

	Grazing Period[2]				
Item	May	June	July	August	September
TDN[3]	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, mg/kg	1,259	1,285	1,107	1,160	1,257
Fe, mg/kg	144	90.50	92.50	77.50	193.67
Cu, mg/kg	4.4	4.20	3.20	2.95	3.70
Zn, mg/kg	18.3	17.85	14.35	15.10	17.23
Mo, mg/kg	1.2	0.95	1.30	1.25	1.37
Mn, mg/kg	86.3	67.30	72.10	84.40	99.77

[1]Clipped forage samples from 10 different locations reported herein are composite over all locations within the representative sampling dates.
[2]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).
[3]$TDN = 88.9 - (0.79 \times ADF\%)$; Lardy, 2018

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

	Intake Category[1]			
Item, µg/g	High	Low	SEM	*P*-Value
n	9	9		
Se	2.92[a]	2.41[b]	0.10	< 0.01
Fe	202	220	22	0.58
Cu	247[a]	116[b]	22	< 0.01
Zn	111	119	17	0.74
Mo	3.98	3.75	0.29	0.59
Mn	9.74	8.84	0.50	0.22
Co	0.51[a]	0.27[b]	0.05	< 0.01

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

[1]Cow divergent mineral intake classified cows as HIGH (> 90 g/d) or LOW (< 90 g/d) mineral intake.