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REGULAR ARTICLES

Use of radio-frequency identification technology to assess the frequency of cattle visits to mineral feeders

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Abstract

Three experiments were conducted to evaluate the frequency of visits to a mineral feeder equipped with radio-frequency identification (RFID). In Exp. 1, twelve heifers (Braford, Brahman, and White Angus; n = 4/breed) were fitted with RFID ear tags and placed into a pasture with access to a RFID-equipped mineral feeder. Number of visits were greater ($P \leq 0.05$) during daytime than the night period. Brahman and Braford heifers favored ($P \leq 0.05$) daytime than night period. White Angus heifers did not display a specific period preference ($P = 0.32$). In Exp. 2, Black Angus and Brahman cows (n = 15 and 19, respectively) were placed into a pasture with access to a RFID-equipped mineral feeder. Brahman cows made more ($P < 0.01$) visits to the mineral feeder than Black Angus cows. There were no breed differences on the number of visits during the morning ($P = 0.25$) and night ($P \leq 0.25$) periods, but Brahman cows made more ($P \leq 0.05$) visits to the mineral feeder in the afternoon period than Black Angus cows. In Exp. 3, the location of the mineral feeder was tested using 3 groups of *Bos indicus*–influenced heifers (n = 12/group). The mineral feeder was moved weekly within pasture. The number of visits to the mineral feeder differed for each location ($P < 0.001$) with visits being greatest when mineral feeder was placed near supplement and water, followed by center of the pasture, and lastly in the shade.

Keywords Cattle behavior · Feeder visits · Free-choice mineral supplement · Radio-frequency identification

Introduction

In almost all regions of the world, grazing cattle experience mineral imbalances. The mineral composition of forages does not always equate to the nutritional requirements of cattle. In some regions, the mineral concentration of forages can exceed cattle requirements, as in the case of Cu, Fe, Mo, and Se, leading to toxicity. Nonetheless, in most of the regions, the scenario is the opposite and Ca, P, Na, Co, Cu, I, Se, and Zn are the minerals most likely to be lacking for ruminants under grazing conditions (McDowell 1996).

In tropical and subtropical climates, where a large percentage of the world's beef is produced, cattle typically graze year-round. In these environments, supplementation strategies are critical to cowherd productivity. Often, free-choice, salt-based mineral supplements are offered with the anticipation of adequate intake to offset nutrient deficiencies. However, variation in intake of free-choice supplements is a common problem that affects the efficiency of this supplementation strategy (Greene 2000).

Fluctuation in mineral supplement consumption by grazing cattle can be affected by many factors. Season of the year and dietary energy and protein can influence mineral supplement consumption, as well as, individual requirements, palatability of the product, and salt content of the water. Furthermore, geographical location can impact mineral supplement consumption due to differences in soil properties and forage species (McDowell 1996; Arthington 2015).

Although much of the variation in consumption of mineral supplements has been addressed in the literature, many questions still need to be answered, including the variation

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in mineral supplement consumption among breeds, cattle preferences for mineral feeder location, and daily distribution of visits to the mineral feeder.

We hypothesized that different cattle breeds would have a different preference for a specific period of the day to visit a mineral feeder, likely resulting in different number of visits among breeds. Similarly, we hypothesized that cattle would have a preference for specific mineral feeder location, resulting in variation in the frequency of visits to a mineral feeder due to the location. Therefore, the objective of this study was to describe the pattern of cattle visits to a mineral feeder, considering periods of the day, location of mineral feeder, and cattle breed.

Material and methods

Three experiments were conducted from May 2016 to January 2017 at the University of Florida, Range Cattle Research and Education Center (Ona, FL; 27° 23′ N, 81° 57′ W, 24 m altitude). General animal husbandry practices for grazing beef cattle were used throughout each study (National Research Council 2011).

Radio-frequency technology

To conduct the experiments, our team engineered and developed radio-frequency identification (RFID) technology to accurately assess the frequency of cattle visits to a mineral feeder. Radio-frequency identification systems employ low-frequency radio signals to transfer information between a transponder that contains the unique identification code and an antenna that collects the signal and transfers it to a decoder (McAllister et al. 2000). Each mineral feeder was custom-designed and equipped with an antenna and tag reader (i.e., decoder; Aleis Readers, Model 8164. Queensland, AU). Each animal had its own numbered tag, coupled with a transponder (Model HDX; Allflex, TX, USA) that had a unique identification (ID). Readers were set to automatically scan for the presence of any tag and read the same ID in intervals of 3 min, allowing for multiple IDs to be read at the same interval. In an interval of 10 min, for example, an ID would be read 3 times. Each ID was recorded with time and date stamped. Interval visits were established based on initial data where length of visits was recorded on 30-s intervals resulting to be on average 3 min long. Previous research with similar technology used a similar interval length to describe a visit to the mineral feeder (Cockwill et al. 2000). The mineral feeders were built to allow single animal entry to the feeder. Additionally, the readers were protected with a metal box, which would only allow the IDs to be read when an animal had its head inside of the mineral feeder and above the mineral container placed inside of the mineral feeder (Fig. 1). Readers were powered with a dual-purpose battery (EXIDE, Battery Systems; Garden Grove, CA), which was recharged and replaced weekly.

The accuracy of the readers was verified using a game camera (Long Range IR®, Cuddeback; De Pere, WI). The camera was placed inside the mineral feeder to match pictures of the IDs with the readings provided by the readers.

Data management

Readings were collected every week, and reader's settings were checked every day to confirm the interval between readings (3 min) and the battery level. The readers did not present any failure during the experiments. To ensure accuracy of data, recorded readings were scanned for missing values that occurred when the storage of readings was limited by the level of the battery (i.e., battery was dead). Readings were evaluated in cycles of 24 h and were organized in a manner to respect these intervals. If the reader stopped recording data, the next reading to be added to the file was the first reading of the same period, however later than the last reading recorded. The in-between readings were then deleted. For example, if the reader stopped working on the 5th of May at 1100 h, and begin to work again on the 7th of May at 0800 h, there was 1 day missing (6th of May) and the readings of May 7th from 0800 to 1100 h were deleted and the first reading after 1100 h on May 7 was added to the file for the consistency of the data respecting the cycles of 24 h. Frequency of visits was calculated in 8-h intervals: morning = 0500 to 1259 h, afternoon = 1300 to 2059 h, and night = 2100 to 0459 h. Daily intervals, morning, afternoon, and night, were categorized using Microsoft Excel®.

Fig. 1 Mineral feeder equipped with reader. The mineral feeder had a movable shelf for adjustable placement of mineral supplement (front; A). The reader was placed in the back of the mineral feeder (B) and protected with a metal box. Dimensions (cm): front, 200 height × 173 width; back, 160 height × 90 width; side length 150

Animals, mineral supplements, and locations

In both experiments, 1 and 2, the breed preference for period of day (morning, afternoon, and night) to visit the mineral feeder was evaluated.

In Exp. 1, visits were recorded from May to July 2016, resulting in approximately 1400 readings for 47 days. During the length of the experiment, Braford, Brahman, and White Angus purebred heifers (n = 4/breed) were allocated in a "Jiggs" bermudagrass (*Cynodon dactylon*) pasture with access to one mineral feeder. The pasture followed a slightly squared design (approximately 10 ha) with natural shade of mature trees scattered throughout the pasture. There was only one water source, which was located centrally in the pasture.

In Exp. 2, visits were recorded from September to October of 2016. Purebred Brahman and Black Angus cows (n = 19 and 15, respectively) were allocated in the same pasture used in Exp. 1, with access to one mineral feeder for 35 days, resulting in approximately 690 readings. In Exp. 2, a bale of "Jiggs" bermudagrass (*Cynodon dactylon*) hay was available as forage availability became limited.

In Exp. 3, visits were recorded from October to December of 2016 over 63 days. Thirty-six *Bos indicus*–influenced heifers were divided in 3 groups (n = 12/group) and put onto three Limpograss (*Hemarthria altissima*) pastures with access to one mineral feeder per pasture. To assess the effect of location on the frequency of mineral feeder visits, the mineral feeders were relocated weekly within the pasture (1) to the center of the pasture, (2) under the shade, and (3) near supplement and water. The feeder's position was the same across all three pastures. Feeders were in the same location 3 times for the length of the study. While in the same location, feeders were positioned exactly as they were positioned the previous time at that location. All three pastures were similarly designed in rectangular shape (approximately 3 ha) having only one source of water and shade. Water was located in the center front of the pastures and natural shade was available alongside the fence in the back end of the pastures. In each pasture, a round bale of "Jiggs" bermudagrass (*Cynodon dactylon*) hay was available as forage availability became limited. A new hay bale was provided every week for each pasture.

Mineral supplement (Table 1) consumption was evaluated throughout the 3 experiments. Intake was calculated by the disappearance rate of the supplement. The mineral supplement was provided at the beginning of the study (22.7 kg) and weighed weekly to estimate the daily intake of the supplement. Mineral intake calculation was done by subtracting the weight of the supplement from the current week to the weight of the previous week, then divided by 7 (days of week) and then divided by the number of animals in each group. Mineral supplement was replaced when supplement weight was below 4.5 kg. At this point, the remaining mineral supplement was discarded, and a new bag (22.7 kg) of mineral supplement was provided. In Exp. 3, once the supplement had to be replaced for one group, it was replaced for all the other groups.

Table 1 Nutrient composition of mineral supplement[1]

Item	Exp. 1[2]	Exps. 2 and 3[2]
% (DM basis)		
Ca	9.10	16.80
P	4.00	4.00
NaCl	62.50	20.70
Mg	1.00	1.00
mg/kg (DM basis)		
Cu	1750	1750
Se	60.00	60.00
Zn	5000	5000
Co	-	60.00
I	-	350

[1]Mineral supplements composition based on manufacturer label

[2]In all experiments, mineral supplement was offered as free choice. Supplement was replaced when supplement weight was below 4.5 kg

Temperature and humidity parameters

Temperature and humidity parameters were collected at the Ona location of FAWN (Florida Automated Weather Network; Gainesville, FL) from May 2016 to January 2017 (Table 2).

A variety of indices are used to estimate the degree of heat stress affecting cattle. The temperature-humidity index (THI) is one of the most common indices, which uses temperature and humidity parameters to estimate the magnitude of heat stress (Dikmen and Hansen 2009).

The Livestock Weather Safety Index (LWSI) provides an interpretation for THI values as follows: normal, ≤ 74; alert, $74 < \text{THI} < 79$; danger, $79 \leq \text{THI} < 84$; and emergency, $\text{THI} \geq 84$ (Mader et al. 2006). In this study, the THI data was calculated for each month according to the equation provided by Mader et al. (2006): $\{\text{THI} = [0.8 \times \text{ambient temperature}] + [(\% \text{ relative humidity} \div 100) \times (\text{ambient temperature} - 14.4)] + 46.4\}$.

Statistical analysis

All data were analyzed for normality using the UNIVARIATE procedure of SAS (SAS Inst., Inc., Cary, NC; version 9.4). Data were considered normally distributed based on the Shapiro–Wilk statistic test.

Table 2 Minimum and maximum temperature, relative humidity, and calculated THI from May 2016 to January 2017

Month[1]	Minimum temperature (°C)[2]	Maximum temperature (°c)[2]	Relative humidity (%)[2]	Calculated THI[3]
May	17.1	30.9	77	73
June	22.1	32.6	85	78
July	23.6	35.4	84	80
August	23.2	33.1	82	79
September	22.2	32.9	86	78
October	18.8	29.9	81	73
November	12.6	27.0	79	65
December	14.3	27.0	83	67

[1]THI values were calculated for each month of the study. Exp. 1: May to July 2016; Exp. 2: September to October 2016; and Exp. 3: October to December 2016

[2]Temperature and humidity parameters were collected at the Ona location of FAWN (Florida Automated Weather Network; Gainesville, FL; 27° 23′ N, 81° 57′ W, and 24 m altitude) from May 2016 to January 2017

[3]THI data was calculated for each month according to the equation provided by Mader et al. (2006): THI = [0.8 × ambient temperature] + [(% relative humidity ÷ 100) × (ambient temperature − 14.4)] + 46.4}

Table 3 Effect of breed and period of the day on the number of weekly visits to the mineral feeder among yearling beef heifers during Exp. 1[1]

Breed[3]	Periods[2]		
	Morning[4]	Afternoon[4]	Night[4]
Braford	$7.03^{a,X}$	$5.60^{b,X,Y}$	$3.25^{a,b,Y}$
Brahman	$7.96^{a,X}$	$8.32^{a\dagger,X}$	$2.15^{b,Y}$
White Angus	$4.78^{b,X}$	$6.43^{a,b,X}$	$4.75^{a,X}$

[1]Data collected over 47 days from May to July 2016. Heifers were grazing fertilized "Jiggs" bermudagrass pasture. Visits are presented as the average number of weekly visits per period

[2]Largest SEM = 0.685 and 1.015, respectively, for breed and period

[3]Breeds consisted of Braford (n = 4), Brahman (n = 4), and White Angus (n = 4)

[4]Distribution of visits were reported in 8-h intervals: morning = 0500 to 1259 h, afternoon = 1300 to 2059 h, and night = 2100 to 0459 h

[a,b]Number of visits in a column with different superscript differs ($P \leq 0.05$)

[X,Y]Number of visits in a row with different superscript differs ($P \leq 0.05$)

[†]Brahman heifers tended ($P = 0.08$) to visit the feeder more in the afternoon when compared to the White Angus heifers

All data were analyzed using the GLIMMIX procedure of SAS. In each experiment, animal was the experimental unit. In Exps. 1 and 2, the number of visits as weekly average was the dependent variable. Model statement included the effects of period (morning, afternoon, and night), breed, and the interaction. The random statement included week. In Exp. 3, number of visits as the daily average was the dependent variable. Model statement included the effects of location and the random statement included group and week.

Data were separated using PDIF when a significant *F*-test was detected. Results are reported as least squares means. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and $P \leq 0.10$.

Results

Experiment 1

All heifers visited the feeder at least once for the durations of the study and visits were consistently distributed throughout the day. Effects of period ($P < 0.01$) and period × breed were observed ($P = 0.05$).

There were no differences ($P = 0.89$) on the number of visits when comparing morning and afternoon periods; however, both periods had greater ($P \leq 0.05$) number of visits when compared to the night period. During morning, Brahman and Braford had a greater ($P \leq 0.05$) number of visits compared to White Angus. There were no differences ($P = 0.38$) for the number of visits in the morning period when comparing Brahman and Braford. During the afternoon, Brahman heifers had a greater ($P \leq 0.05$) number of visits compared to Braford and tended ($P = 0.08$) to have a greater number of visits compared to White Angus. There were no differences ($P = 0.44$) when comparing White Angus and Braford heifers. No differences ($P = 0.16$) for the number of visits were observed at night when comparing Braford and Brahman, or Braford and With Angus. However, White Angus heifers had a greater ($P \leq 0.05$) number of visits when compared to Brahman heifers at night (Table 3).

The preferences within breed for each period were also evaluated. Braford heifers had a greater ($P \leq 0.05$) number of visits to the mineral feeder in the morning compared to night with no differences between morning and afternoon ($P = 0.40$) or afternoon and night periods ($P = 0.16$). Brahman heifers numerically favored daylight visits to the mineral feeder. However, there were no differences ($P = 0.83$) among Brahman visits when comparing morning and afternoon, but both morning and afternoon number of visits were greater ($P \leq 0.01$) than visits at night. Interestingly, White Angus did not display any specific preference for visits to the mineral feeder during the different periods of the day ($P = 0.32$).

Mineral supplement intake was recorded and calculated by the disappearance rate. During the evaluation period, mineral supplement intake ranged from 38.1 to 129.9 g/heifer daily, resulting in an average of 78.5 g/heifer daily.

During the experiment, heifers experienced periods where the consumption of the supplement was below the target (50 g/heifer daily) and periods when consumption was above the target.

Experiment 2

All cows visited the feeder at least once for the durations of the study. Effects of breed ($P<0.01$), period ($P=0.05$), and a tendency for breed × period ($P=0.07$) were observed.

Overall, Brahman cows visited the mineral feeder more frequently than Black Angus cows ($P<0.01$; 1.17 and 0.50, SEM = 0.174, respectively). Total number of visits for Black Angus and Brahman cows was greater ($P=0.05$) in the afternoon compared to morning. There were no differences ($P=0.49$) for visits when comparing morning and afternoon to night (Table 4). Brahman cows made more ($P<0.01$) visits to the mineral feeder than Black Angus cows. There were no breed differences on the number of visits during the morning ($P=0.25$) and night ($P\leq0.25$) periods, but Brahman cows made more ($P\leq0.05$) visits to the mineral feeder in the afternoon period than Black Angus cows.

There were no differences ($P\leq0.25$) in visits between Brahman and Black Angus during morning or night; however, Brahman cows visited the mineral feeder more ($P\leq0.01$) frequently in the afternoon compared to Black Angus cows.

Within breed, Brahman cows had a greater number of visits to the mineral feeder during the afternoon compared to morning ($P\leq0.01$) and night ($P=0.05$), while Black Angus cows did not ($P=0.79$) display a preference for a specific time of day when visiting the mineral feeder; however, the number of visits were numerically greater for the night period.

Mineral supplement intake ranged from 15.3 to 53.6 g/cow daily, resulting in an average of 29.9 g/cow daily. In Exp. 2, average mineral intake never reached the recommended target amount (50 g/cow daily).

Table 4 Effect of breed of cows on the number of weekly visits to the mineral feeder among purebred Brahman and Black Angus cows during Exp. 2[1]

Breed[3]	Periods[2]		
	Morning[4]	Afternoon[4]	Night[4]
Black Angus	$0.35^{a,X}$	$0.45^{b,X}$	$0.70^{a,X}$
Brahman	$0.70^{a,Y}$	$1.70^{a,X}$	$1.10^{a,Y}$

[1]Data collected over 35 days from October to December 2016. Cows were grazing fertilized "Jiggs" bermudagrass pasture. Visits are presented as the average of weekly visits per period

[2]Largest SEM = 0.1433 and 0.2027, respectively, for breed and period

[3]Breeds consisted of purebred Black Angus (n = 15) and Brahman (n = 19) cows

[4]Distribution of visits were reported in 8-h intervals: morning = 0500 to 1259 h, afternoon = 1300 to 2059 h, and night = 2100 to 0459 h

[a,b]Number of visits in a column with different superscript differs ($P\leq0.05$)

[X,Y]Number of visits in a row with different superscript differs ($P\leq0.05$)

Experiment 3

All heifers made at least one visit to the mineral feeder in each location. Visits to the mineral feeder were reported as the daily average of visits in the specific target locations, which were relocated weekly within pasture in the following order: (1) center of the pasture, (2) under the shade, and (3) near supplement and water.

The frequency of visits differed ($P<0.001$) for each location with location next to water and supplement having the greatest number of visits (2.44 visits/day), followed by center of the pasture (1.60 visits/day), and lastly the shade (0.97 visits/day).

Mineral supplement intake ranged from 1.30 to 85.60 g/heifer daily, resulting in an average of 33.4 g/heifer daily. Similarly, to Exp. 2, heifers never reached the targeted daily intake.

Discussion

In Exp. 1, heifers made more visits to the mineral feeder during the afternoon period. The second most visited period was the morning period, and the last frequented period was the night period. There were no differences on the number of visits to the mineral feeder when comparing morning and afternoon periods. Additionally, both periods, morning and afternoon, had more visits when comparing to the period of the night.

Despite the effects of heat on behavior of cattle (Silanikove 2000) in this experiment, heifers continuously seek the mineral feeder during the light hours showing a decrease in activity (approximately 50%) during the period of night. Although THI values for the respective period were in the range of alert to danger (73, 78, and 80 respectively for May, June, and July), these data suggest that younger heifers are more engaged in feeding activities, including mineral consumption, during the daylight, which is in agreement with previous studies. Tait and Fisher (1996) in a similar study evaluated steer's frequency and preference of visits to the mineral feeder and found a greater number of visits to the mineral feeder occurring during late evening as seen in Exp. 1 of the current study.

The preferences of each breed for a specific period of the day were also evaluated. Braford heifers made more visits to the mineral feeder during the morning period, while

Brahman heifers made more visits to the mineral feeder during the afternoon period. As addressed by Hansen (2004), these data suggest that Brahman heifers are more resistant to the heat of the day when compared to the Braford heifers, and consequently, Brahman heifers were able to make more visits to the mineral feeder during the time of the day with the highest temperatures. Interestingly, the White Angus heifers had no preferences for a specific period of the day, although the number of visits to the mineral feeder were numerically greater during the afternoon, which may suggest a greater ability to cope with high temperatures as seen in this experiment for the months of May, June, and July (30.9, 32.6, 35.4 °C, respectively). The White Angus is a distinct beef cattle phenotype that was developed at the University of Florida, Range Cattle Research and Education Center (Ona, FL). Previous research (Gebremedhin et al. 2008) reported that when grazing summer pastures with no access to shade, White Angus heifers had a 1.1 °C lower body temperature compared to Black Angus heifers. Additionally, White Angus heifers exhibited a greater sweating rate when compared to the Black Angus heifers, which may explain the ability of the White Angus heifers to deal with the heat of the day almost as well as the Brahman heifers, and therefore not exhibiting a preference for a specific time of the day to visit the mineral feeder.

In Exp. 2, Brahman cows made more visits to the mineral feeder than Black Angus cows. Although the number of visits may not necessarily be reflected in the actual mineral supplement intake, it is possible that a greater number of visits to the mineral feeder in fact results in greater mineral supplement intake, which could possibly translate into different mineral requirements among breeds. Ranches et al. (2021) reported differences in Cu and Se metabolism of Brahman and Angus cows over a long-term study that manipulated the level of antagonists in the diet. In that study, several differences in markers used for mineral assessment in cattle were reported between the two breeds. Collectively, these findings imply that cattle mineral requirements might differ among breeds.

Brahman cows had a greater number of visits to the mineral feeder in the afternoon compared to morning, while Black Angus cows showed no preference for a specific period of the day. This pattern of visits to the mineral feeder for the Brahman cows was similar to the pattern observed by Cockwill et al. (2000) who evaluated the visits of cows and calves to the mineral feeder and found that cows made more visits to the mineral feeder during the afternoon.

According to Braghieri et al. (2011), cows are more engaged in grazing and walking activities during morning and afternoon, which can eventually lead to a greater number of visits to the mineral feeder in these periods as seen in this experiment for the Brahman cows. Additionally, Manzano et al. (2012) suggested that the attendance to the mineral feeder is affected by sunlight, temperature, and grazing patterns. Accordingly, the pattern of the visits observed for the two breeds in this experiment is likely explained by natural cattle behavior and the ability of the two breeds to cope with heat. Brahman cattle are known to be more tolerant to heat when compared to Angus cattle (Hammond et al. 1996) because of particular characteristics of *Bos Indicus*, such as lower tissue resistance to heat flow from the body core to the skin, smooth and shiny hair coats acting to reduce heat exchange via radiation, and greater size and higher density of sweat glands (Hansen 2004). Therefore, Brahman cows were able to visit the mineral feeder during the hot hours of the day, while the Black Angus cows had a numerically greater number of visits to the mineral feeder during the night, perhaps in an attempt to avoid the hottest hours of the day.

In Exp. 3, the preference for a location of the mineral feeder followed the order: near to supplement and water, followed by center of the pasture, and lastly under the shade. According to Senft et al. (1985), cattle spend a significant portion of daytime resting near water. Therefore, the proximity of the mineral feeder to the supplement and water is likely the factor that explains the greatest number of visits to the mineral feeder when compared to the other locations.

Interestingly, the number of visits was the lowest when mineral feeder was placed under the shade. Considering the low temperatures for the months of November (12.6 and 22 °C, respectively for minimum and maximum) and December (14.6 and 22 °C, respectively for minimum and maximum), it is possible that at this time of the year and temperatures, the heifers were in fact avoiding shaded areas and seeking sunny areas, which would explain the greater number of visits when the mineral feeder was place in the center of the pasture with full exposure to solar radiation. Additionally, the mineral intake observed in these studies was below the daily target intake in Exps. 2 and 3, which were conducted during fall and winter seasons. Although mineral supplement intake is often greatest during winter season and/or dry season, the pattern observed in this study is often observed in Florida, where mineral supplement refusal is often the greatest during the winter months (McDowell and Arthington 2005). Therefore, regardless of the season of the year and temperature, knowing that visits to the mineral feeder can be manipulated by the location of the feeder is an important tool for beef cattle producers in order to increase or decrease the number of visits to the mineral feeder, and consequently optimize mineral intake.

In summary, breed, period of a 24-h day, and location of the mineral feeder are all factors that express some influence on the number of visits to the mineral feeder, which will likely influence the consumption of the mineral supplements. Collectively, these data provide practical insights of mineral supplementation for beef cattle producers, whom when planning mineral supplementation strategies should consider the specific formulation of each mineral supplement and the behavioral information provided by this study.

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Code availability Not applicable.

Declarations

Ethics approval General animal husbandry practices for grazing beef cattle were used throughout each study (National Research Council, 2011).

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Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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