Intake behaviors of yearling steers grazing irrigated pasture and receiving either a free-choice salt-based mineral or a low-moisture molasses-based tub mineral

Joel V. Yelich,* Melinda J. Ellison,*[,1] John B. Hall,* and Marcus McGee†

*Nancy M. Cummings Research, Extension, and Education Center, University of Idaho, Carmen, ID 83462; and †Northwest Missouri State University, School of Agricultural Sciences, Maryville, MO 64468

ABSTRACT: Mineral intake in grazing cattle is highly variable and research evaluating behavioral aspects of intake are minimal. Development of the GrowSafe System to monitor feed intake allows researchers to record individual feeding behaviors of cattle 24 h per day. In the current experiment conducted during June and July, the GrowSafe System was utilized to evaluate intake behaviors of grazing steers during a short-term free-choice supplementation of either salt-based loose minerals (**LM**; n = 24; 408 ± 57 kg) or low-moisture molasses-based tub minerals (**TUB**; n = 24; 396 ± 64 kg). Each treatment was randomized to two of the four irrigated pastures (~5 ha each) consisting of orchard grass (*Dactylis glomerat* L.), red clover (*Trifolium pretense* L.), and smooth brome (*Bromus inermis*). Individual intake was evaluated over three 7-d periods: d – 7 to 0 (adaptation period; **AP**), d 1 to 7 (period 1; **P1**), and d 15 to 22 (period 2; **P2**) of the experiment. The LM mineral mix contained 28% salt during the AP and more salt was added at the initiation of P1 to prevent excessive mineral intake observed during the AP. The LM mineral mix contained 38% salt during P1 and P2. Daily bunk attendance was greater (P < 0.001) for LM (93%) than TUB (67%) steers for the AP. Whereas there was a treatment × period effect (P < 0.001) on daily bunk attendance across P1 (LM: 92%; TUB: 64%) and P2 (LM: 91%; TUB: 82%). Daily mineral intake (as-fed) was greater (P < 0.001) for LM (568 g) than TUB (283 g) during the AP. For P1 and P2, there were no treatment (P = 0.46) and period (P = 0.77) effects on daily mineral intake (LM, 370 g vs. TUB, 343 g), but LM (3.1 visits) had more (P < 0.001) bunk visits per day than TUB (2.0 visits). During the AP, LM (8.5 min) had a greater (P = 0.04) duration of mineral intake per day than TUB (5.6 min); whereas during P1 and P2, TUB (P1 = 8.6; P2 = 12.8 min) had a greater (P ≤ 0.05) duration of mineral intake per day than LM (P1 = 4.9; P2 = 5.7 min). In conclusion, mineral delivery method significantly affected bunk attendance, number of bunk visits per day, and time spent consuming mineral. These results provide additional evidence that mineral type and associated feeding behaviors contribute to the significant variation observed in daily mineral intake in grazing cattle.

Key words: beef, behavior, grazing, GrowSafe, trace minerals

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INTRODUCTION

Trace minerals are essential to the total nutritional requirements of yearling cattle grazing forages. Mineral availability in forages changes depending on forage quality, soil type, soil fertility,

[1]Corresponding author: ellison@uidaho.edu
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and geographic location (Greene, 2000; McDowell, 2003). Trace minerals can be delivered to grazing cattle in protein-/energy-based supplements, salt-based loose minerals, pressed blocks, liquid supplements, and solid tubs (Greene, 2000). It is difficult to measure individual cattle intake of trace minerals 24 h per day for extended periods of time. Moreover, considerable variability exists in mineral intake of grazing animals over time (Tait and Fisher, 1996; Dixon et al., 2001) and season (Manzano et al., 2012). There is limited work evaluating intake behaviors of grazing cattle receiving free-choice trace mineral supplements (Manzano et al., 2012). A better understanding of mineral intake behaviors of cattle grazing forage could provide valuable information for producers on how to deliver free-choice minerals more effectively and possibly reduce costs associated with mineral delivery.

Development of electronic radio frequency identification tags (RFID) allows researchers to collect individual feeding behavior data of cattle maintained in groups (Eradus and Jansen, 1999; Schwartzkopf-Genswein et al., 2002; McGee et al., 2014). Moreover, RFID systems can be used to monitor individual feeding behaviors based on attendance and duration of time spent at the feed bunk (Quimby et al., 2001; Mendes et al., 2011). The GrowSafe System (GrowSafe Systems Ltd, Airdrie, Alberta, Canada) has been used to monitor 24 h intake behaviors of mineral in a nominal number of studies including cows supplemented with either loose mineral- or molasses-based blocks (Cockwill et al., 2000) and grazing steers receiving loose mineral (Manzano et al., 2012). Additional information is needed to better understand consumption patterns and associated behaviors in cattle receiving mineral supplements via different delivery methods.

The objective of this study was to evaluate daily intake behaviors using RFID-based feed intake recording equipment (GrowSafe System) during a short-term mineral supplementation period of steers grazing irrigated pasture and receiving free-choice of either a salt-based loose mineral or a low-moisture molasses-based tub mineral.

MATERIAL AND METHODS

Study Location and Animal Care

Throughout the experiment, yearling steers were maintained in accordance with acceptable animal practices as outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010). The research protocol was reviewed and approved by the University of Idaho Institutional Animal Care and Use Committee (#2016-39). The experiment was conducted during June 21 to July 29, 2016 at the University of Idaho, Nancy M. Cummings Research, Education, and Extension Center, Carmen, Idaho, which is located at latitude 45°31′07″N, and longitude 114°18′54″W. During the experimental period, mean daily temperature was 19°C (range 5–36°C), mean daily relative humidity was 43.3% (30–93%), and total precipitation was 0.20 cm.

Experimental Design and Animals

Using a completely randomized design consisting of two treatments, Angus cross steers (n = 48) were weighed on d −8 and −7 of the experiment and stratified by body weight (**BW**) into one of the four irrigated pastures (~5 ha) consisting of orchard grass (*Dactylis glomerat* L.), red clover (*Trifolium pretense* L.), and smooth brome (*Bromus inermis*). Four GrowSafe units (GrowSafe Systems Ltd) were mounted on a single, uncovered concrete pad at a central location of the four pastures. Steers were given free-choice access to forage and water (located at the opposite end of the pasture from the mineral supplements) throughout the experiment.

Steers in two of the pastures were provided a custom-made free-choice salt-based loose mineral supplement (**LM**: pasture 1, n = 12 steers, initial BW = 405 ± 45 kg; pasture 3, n = 12 steers, initial BW = 406 ± 66 kg; Custom Grazing Mineral; Simplot Western Stockmen's, Caldwell, ID; 94% DM, 12.0, 0.36, 5.0, 8.0, and 6.0% of Ca, K, Mg, NaCl, and P, respectively, and 2,000, 38, 2,000 ppm Cu, Se, and Zn, respectively). For the LM treatment (pastures 1 and 3), loose salt was added to the base LM mix from d −7 to 0 (adaptation period) of the experiment resulting in a final mineral mix containing 28% salt. To manage for excess daily mineral intake observed during d −7 to 0, beginning on day 1 until the end of the experiment, additional salt was included in the adaptation mineral mix resulting in a final mix containing 38% salt. Steers in the other two pastures were given a commercially available free-choice low-moisture molasses-based (65%) tub mineral supplement (**TUB**: pasture 2, n = 12 steers, initial BW = 406 ± 65 kg; pasture 4, n = 12 steers, initial BW = 393 ± 59 kg; MineralLic; New Generation Supplements, Belle Fourche, SD; 95% DM, 5.5, 1.8, 3.0, and 4.0% of Ca, K, Mg, and P, respectively, and 10, 850, 42, 13.2, 3,400 ppm Co, Cu, I, Se, and Zn, respectively, and 120,000, 12,000, and 10 IU/lb of Vit A, D, and E, respectively). For the TUB treatment, a single tub containing 57 kg of mineral supplement was placed inside the feed bunk of each GrowSafe unit (pastures 2 and 4) at the initiation of the experiment where they remained until the end of the experiment. Additionally, it should be noted that the TUB formulation has no added protein. The mineral product is processed in a proprietary cooking/dehydration process resulting in a glassing of the product, which serves as a physical intake limiter. Moreover, there was no NaCl in the TUB mineral and no loose NaCl was offered to TUB steers throughout the experiment. Individual mineral intake and associated behaviors were evaluated using the GrowSafe System. Steers were introduced to the GrowSafe System for a 7 d adaptation period, followed by two 7 d trial periods. Final full BW on all steers were taken on days 29 and 30 of the experiment.

Mineral Intake Evaluation

Individual steer intake, number of bunk visits, and duration of a feeding event over a 24-h period (0000 to 2400 h) were measured using the GrowSafe System. Two steers, one from each treatment, were removed from the experiment for health issues. One LM steer and three TUB steers had no bunk attendance or mineral consumption during all three periods. These animals were removed from the trial because it was unclear whether their lack of intake was due to unfamiliarity with the GrowSafe bunk or disinterest in consuming mineral.

Statistical Analysis

Mineral intake and behavioral data were analyzed in two separate analysis, including one for the adaptation period (**AP**) of days −7 to 0, and the other consisting of the two data collection periods of days 1 to 7 **(P1**), and days 15 to 22 (**P2**) of the trial. A 7-d AP was chosen because a similar period was used in multiple research studies using GrowSafe System (Cockwill et al., 2000; Garossino et al., 2003) to monitor mineral intake. The two 7-d collection periods were chosen because they provided uninterrupted data collection from all steers across treatments, days, and periods. During the AP, continuous variables were analyzed with PROC MIXED of SAS (Statistical Analysis System, SAS Institute Inc., Version 9.4, Cary, NC). Day was analyzed as a repeated measure with steer as the experimental unit, and main effects of treatment, day, and treatment × day with a random statement that included steer (treatment). Bunk attendance, a categorical variable, was analyzed with PROC GLIMMIX of SAS. Day was analyzed as a repeated measure with steer as the experimental unit, and main effects of treatment, day, and treatment × day with a random statement that included day (treatment). For P1 and P2, continuous variables were analyzed with PROC MIXED. Period and day were analyzed as repeated measures with steer as the experimental unit and main effects of treatment, day, period, and all appropriate interactions with a random statement that included steer (treatment × period). Bunk attendance was analyzed with PROC GLIMMIX. Period and day were analyzed as repeated measures with steer as the experimental unit and main effects of treatment, day, period, and all appropriate interactions with a random statement that included day (treatment). To better understand cattle behavior associated with daily mineral intake, effects of day were included in the models for P1 and P2. Consequently, results are presented separately for the treatment × period effects and the treatment × period × day effects. To further evaluate the variation for mineral intake and associated behaviors, the coefficient of variation (**CV**) was determined and is expressed as a percentage value. Correlations were performed to asses for any relationship between daily mineral intake and associated intake behaviors with weather conditions, including daily temperature (mean, minimum, and maximum), daily humidity (mean, maximum), and precipitation during P1 and P2.

The BW and average daily gain (**ADG**) data were analyzed with PROC GLM procedures of SAS. The model statement included steer as experimental unit and the main effects of treatment, pasture, treatment × pasture. There were no significant pasture or treatment × pasture effects on BW and ADG so pasture data were pooled.

Mean comparisons for all analysis were made using the PDIFF function of SAS. Results for continuous variables associated with mineral intake and associated behaviors are reported as least square means while results for the categorical variable of bunk attendance are reported as a percentage. Significance was set at $P \leq 0.05$, and tendencies were determined if $P > 0.05$ and $P \leq 0.10$ for all analysis.

RESULTS

Adaptation Period

Daily bunk attendance is the total number of steers that visited the feed bunk and consumed mineral in 24 h (0000 to 2400 h) divided by the total number of steers in a treatment, and it is expressed as a percentage. Daily bunk attendance was greater ($P < 0.001$) for LM than TUB steers during the AP (Table 1). Although there was a day ($P = 0.02$) effect on daily bunk attendance, there was no treatment × day ($P = 0.39$) effect. There were treatment ($P < 0.001$) and day ($P < 0.001$) effects but no treatment × day ($P = 0.19$) effect on daily mineral intake (Table 1), which was 285 g greater ($P < 0.001$) for LM than TUB steers. There was greater variation in daily mineral intake for TUB steers (CV = 144%) compared with LM steers (CV = 74%). The LM steers (3.4 ± 0.2 visits; CV = 67%) exhibited twice ($P < 0.001$) as many bunk visits per day and less individual variation in the number of bunk visits per day than TUB steers (1.7 ± 0.2 visits; CV = 101%) (Table 1). When mineral intake was analyzed on a per bunk visit basis during the AP, there was a treatment × day ($P = 0.01$) effect, but there was no consistent pattern of mineral intake observed across days. There were treatment × day effects on the mean duration of mineral intake on both per day ($P = 0.004$) and per bunk visit ($P < 0.001$). The LM steers were observed to spend a greater duration of time, numerically, for 5 of 7 d consuming mineral each day; while TUB steers were observed to spend a greater duration of time, numerically, for 5 of 7 d consuming mineral at each bunk visit (data not shown). The CV for duration of mineral consumption per day was 90% for LM and 151% for TUB steers, and the CV for duration of mineral consumption per visit bunk was 92% for LM and 167% for TUB steers.

Data Collection: Treatment and Period Effects

There was a treatment × period ($P < 0.001$) effect on daily bunk attendance across P1 and P2. The LM steers had greater ($P \leq 0.01$) daily bunk attendance than TUB steers during P1, while daily bunk attendance was not different ($P = 0.13$) between LM and TUB steers during P2. Daily bunk attendance was not different ($P = 0.86$) from P1 to P2 for LM steers but increased ($P \leq 0.01$) 18.6% from P1 to P2 for TUB steers (Table 2).

During P1 and P2, there were no treatment ($P = 0.46$), period ($P = 0.77$), or treatment × period ($P = 0.90$) effects on daily mineral intake. When pooled across P1 and P2, daily mineral intake was 370 ± 25 g for LM and 343 ± 28 g for TUB steers. However, there was considerable within steer variation observed in daily mineral intake as well as across treatments and periods. This variation also appears to be associated with a cyclic pattern in individual daily mineral intake for LM and TUB steers within each period (data not shown). A general pattern observed consisted of a large peak in daily mineral intake followed by one to several days of decreased intake. The cyclic pattern was further manifested in the considerable range observed in individual daily mineral intake within steers as well as across treatments and periods. Throughout the trial, individual daily mineral intake fluctuated from no mineral consumption to levels greater than 1,400 g per day for LM and TUB steers (Table 2). Furthermore, the CV for daily mineral intake for TUB steers were 124 and 105% for P1 and P2,

Table 1. Treatment (T) and day (D) effects on mean bunk attendance, mineral intakes, and associated behaviors during an adaptation period for steers receiving free-choice access to either a salt-based loose mineral (LM; $n = 22$) or low-moisture molasses-based tub mineral (TUB; $n = 20$) (bunk attendance reported as a proportion and remaining variables reported as least squares means ± SE)

			P-value		
Variable	LM (range)	TUB (range)	T	D	T × D
Daily bunk attendance[1], %	93.5 (72–100)	67.1 (61–83)	<0.001	0.02	0.39
Daily mineral intake[2], g	568 ± 30 (0-1,980)	283 ± 40 (0-1,430)	<0.001	<0.001	0.19
Number of bunk visits per day[3]	3.4 ± 0.2 (0–10)	1.7 ± 0.2 (0–5)	<0.001	0.05	0.90
Mineral intake per bunk visit[4], g	188 ± 11 (0–800)	151 ± 15 (0–630)	0.05	<0.001	0.01
Duration of mineral intake per day[5], min	8.5 ± 1.0 (0–41.1)	5.6 ± 1.1 (0–26.9)	0.04	0.01	0.004
Duration of mineral intake per bunk visit[6], min	2.8 ± 0.6 (0–13.7)	3.6 ± 0.6 (0–20.4)	0.32	0.04	<0.001

[1]Daily bunk attendance = total number of steers that attended the bunk and consumed mineral in 24 h (0000 to 2400) divided by the total number of steers in treatment.

[2]Daily mineral intake = total mineral consumed (as-fed basis) per steer in 24 h (0000 to 2400).

[3]Number of bunk visits per day = number of times a steer visited a bunk and consumed mineral in 24 h (0000 to 2400).

[4]Mineral intake per bunk visit = total mineral consumed (as-fed basis) divided by number of bunk visits in 24 h (0000 to 2400).

[5]Duration of mineral intake per day = total time (min) steer spent with head-down consuming mineral in 24 h (0000 to 2400).

[6]Duration of mineral intake per bunk visit = total time (min) steer spent with head-down consuming mineral divided by total number of bunk visits in 24 h (0000 to 2400).

Table 2. Treatment (T) and period (P) effects on mean bunk attendance, mineral intakes, and associated behaviors for steers receiving free-choice access to either a salt-based loose mineral (LM; n = 22) or low-moisture molasses-based tub mineral (TUB; n = 20) during two, 7-day data collection periods (bunk attendance reported as a proportion and remaining variables reported as least squares means ± SE)

	P1		P2		*P*-value		
Variable	LM (range)	TUB (range)	LM (range)	TUB (range)	T	P	T × P
Daily bunk attendance[1], %	91.5[a] (59–100)	63.5[b] (40–70)	90.9[b] (86–95)	82.1[b] (65–95)	<0.001	<0.001	<0.001
Daily mineral intake[2], g	374 ± 36 (0–1,550)	350 ± 43 (0–1,330)	368 ±35 (0–1,400)	336 ± 38 (0–1,490)	0.46	0.77	0.90
Number of bunk visits per day[3]	3.0 ± 0.2[a] (0–9)	1.8 ± 0.2[b] (0–5)	3.2 ± 0.2[a] (0–12)	2.1 ± 0.2[b] (0–7)	<0.001	0.24	0.81
Mineral intake per bunk visit[4], g	135 ± 12[a] (0–1,030)	217 ± 15[b] (0–810)	123 ± 12[a] (0–690)	171 ± 14[b] (0–840)	<0.001	0.03	0.21
Duration of mineral intake per day[5], min	4.9 ± 1.1[a] (0–24.9)	8.6 ± 1.2[b] (0–37.6)	5.7 ± 1.1[a] (0–31.9)	12.8 ± 1.1[b] (0–50.9)	<0.001	0.02	0.11
Duration of mineral intake per bunk visit[6], min	1.9 ± 0.5[a] (0–13.6)	5.3 ± 0.6[b] (0–32.9)	1.9 ± 0.5[a] (0–11.5)	6.6 ± 0.5[b] (0–30.5)	<0.001	0.24	0.22

[a,b]Means within a *P* and row with different superscripts differ ($P \le 0.01$).

[1]Daily bunk attendance = total number of steers that attended the bunk and consumed mineral in 24 h (0000 to 2400) divided by the total number of steers in treatment.

[2]Daily mineral intake = total mineral consumed (as-fed basis) per steer in 24 h (0000 to 2400).

[3]Number of bunk visits per day = number of times a steer visited a bunk and consumed mineral in 24 h (0000-2400).

[4]Mineral intake per bunk visit = total mineral consumed (as-fed basis) divided by number of bunk visits in 24 h (0000 to 2400).

[5]Duration of mineral intake per day = total time (min) steer spent with head-down consuming mineral in 24 h (0000 to 2400).

[6]Duration of mineral intake per bunk visit = total time (min) steer spent with head-down consuming mineral divided by total number of bunk visits in 24 h (0000 to 2400).

respectively, while CV for LM steers were 86 and 86% for P1 and P2, respectively. Figure 1 further illustrates the variation observed for unadjusted average daily mineral intake ± SD for each individual steer as well as the variation observed across steers within LM and TUB treatments when ranked from lowest to highest. For the LM steers, average daily intake ranged from 182 to 807 g with a standard deviation of 124 to 404 g, while TUB steers ranged from 50 to 608 g with a standard deviation of 51 to 445 g.

There was a treatment ($P < 0.001$) effect on the number of bunk visits per day during P1 and P2 (Table 2), but there were no period ($P = 0.24$) or treatment × period ($P = 0.81$) effects. When pooled across P1 and P2, LM steers (3.1 ± 0.2 visits) attended the bunk more ($P < 0.001$) times per day than TUB steers (2.0 ± 0.2 visits). In alignment with daily mineral intake, there was a great deal of variation in the number of times each steer visited the feed bunk during the day across all periods (Table 2). The CV for a number of bunk visits per day in LM steers were 70, and 80% for P1, and P2, respectively. Whereas CV for number of bunk visits per day in TUB steers were 103, and 79% for P1, and P2, respectively.

During P1 and P2, there were treatment ($P < 0.001$) and period ($P = 0.03$) effects, but there was no treatment × period ($P = 0.21$; Table 2) effect on mineral intake per bunk visit. The TUB steers (194 ± 10 g) consumed more ($P < 0.001$) mineral per bunk visit than LM steers (128 ± 9 g), regardless of period; moreover, when pooled across treatments, more ($P = 0.03$) mineral was consumed per bunk visit in P1 (176 ± 10 g) than P2 (146 ± 9 g).

There were treatment ($P < 0.001$) and period ($P = 0.02$) effects, but no treatment × period ($P = 0.11$) effect on the duration of mineral intake per day (Table 2). The TUB steers spent 5.4 min more per day ($P < 0.05$) consuming mineral than LM steers across P1 and P2. Although, the duration of mineral intake per day was greater ($P = 0.02$) in P2 (9.2 ± 0.7 min) compared with P1 (6.7 ± 0.8 min). Similarly, the duration of mineral intake per bunk visit was greater ($P < 0.001$) for TUB (5.9 ± 0.4 min) than LM (1.9 ± 0.3 min) steers as there were no period ($P = 0.24$) and treatment × period ($P = 0.22$) effects.

Data Collection: Treatment by Period by Day Effects

There was a treatment × day × period effect ($P = 0.004$) on bunk attendance during P1 and P2 (Fig. 2). During P1, LM steers had greater ($P \le 0.05$) bunk attendance for 5 of 7 d compared with

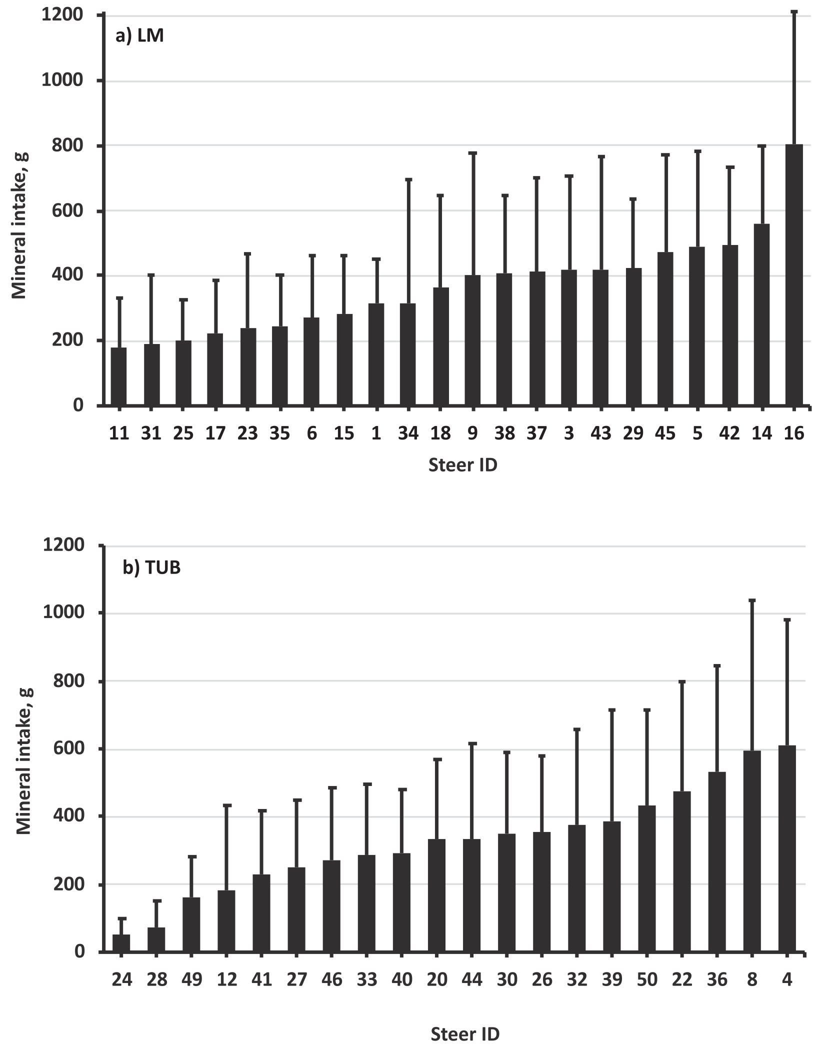

Figure 1. Average daily mineral consumption (±SD) pooled across experimental periods 1 and 2 for individual steers receiving either a) salt-based loose mineral (LM; unadjusted mean intake across all steers = 380 ± 292 g) or b) low-moisture molasses-based tub mineral (TUB; unadjusted mean intake across all steers = 353 ± 287 g).

TUB steers. However, during P2, LM steers only had greater ($P \leq 0.05$) bunk attendance for 2 of 7 d compared with TUB steers, indicating that more TUB steers were attending the bunk and consuming mineral each day as the experiment progressed.

There were no treatment × day ($P = 0.18$), period ($P = 0.77$), day × period ($P = 0.11$), or treatment × day × period ($P = 0.62$) effects on daily mineral intake across P1 and P2, indicating that after the AP, mean daily mineral intake normalized across treatments (data not shown). Although, there was a day ($P = 0.04$) effect on daily mineral intake. Pooled across treatments and periods, daily mineral intake was 365 ± 37, 431 ± 34, 364 ± 34, 300 ± 37, 362 ± 35, 381 ± 32, and 292 ± 35 g for d 1 to 7, respectively.

There was a treatment × day × period ($P < 0.001$) effect on the number of bunk visits per day during P1 and P2 (data not shown). During both P1 and P2, LM steers had a greater ($P \leq 0.05$) number of bunk visits per day than TUB steers for 4 of 7 d. Furthermore, LM steers had a numerically greater number of bunk visits per day than TUB steers for 5 of the 6 remaining days across P1 and P2.

There was also a treatment × day × period ($P = 0.02$) effect on mineral intake per bunk visit (Fig. 3). The TUB steers had greater ($P \leq 0.05$) mineral intake per bunk visit than LM steers for 3 of 7 d in P1 and 1 of 7 d in P2, but there were no clear mineral intake patterns observed across treatments, days, and periods. There was a considerable variation in mineral intake per bunk visit within treatments across periods (Table 2). Moreover, individual variation was greater in TUB steers (CV = 135 and 111% for P1 and P2, respectively) compared with LM steers (CV = 94 and 87% for P1 and P2, respectively).

There was a treatment × day × period ($P < 0.001$) effect on the duration of mineral intake per day for

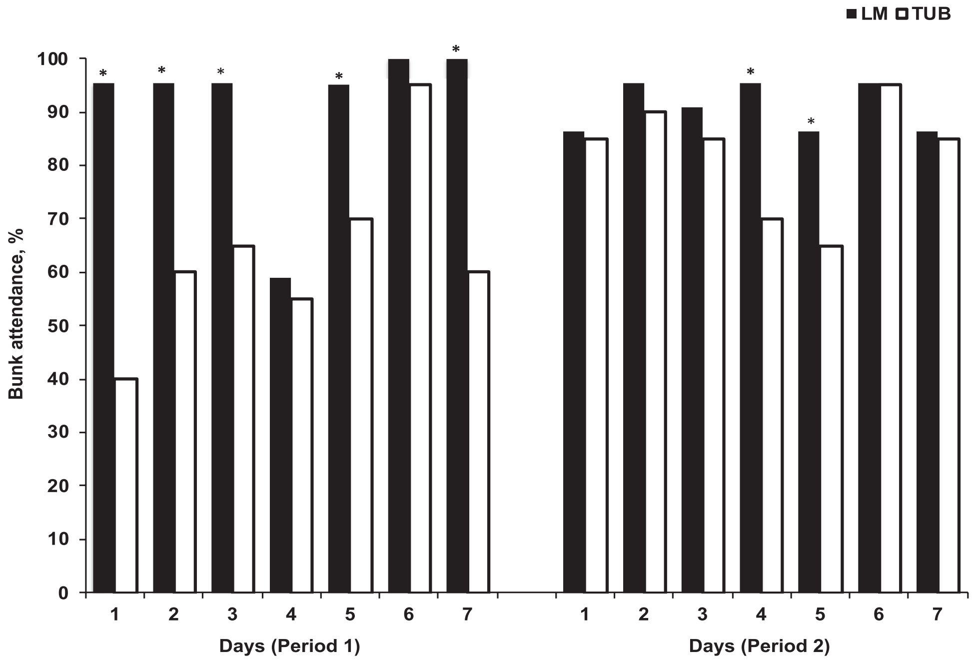

Figure 2. Treatment, day, and period effects on average bunk attendance for steers with free-choice access to either a salt-based loose mineral (LM, $n = 22$) or low-moisture molasses-based tub mineral (TUB; $n = 20$) during two data collection periods (treatment, < 0.001; period $P < 0.001$; day, $P < 0.001$; treatment × period, $P < 0.001$; treatment × day, $P = 0.24$; period × day, $P = 0.01$; treatment × day × period, $P = 0.004$). Means within a period and day with different superscripts differ (*$P \leq 0.05$).

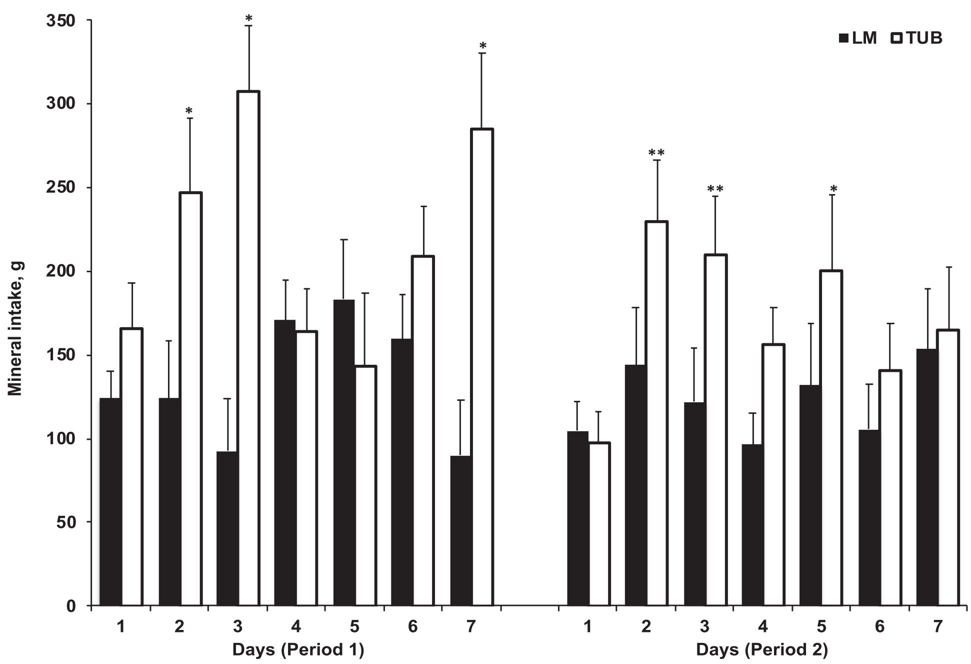

Figure 3. Treatment, day, and period effects on average mineral intake per bunk visit (least squares means ± SE) on an as-fed basis for steers with free-choice access to either a salt-based loose mineral (LM, $n = 22$) or low-moisture molasses-based tub mineral (TUB; $n = 20$) during two data collection periods (treatment, $P < 0.001$; period $P = 0.03$; day, $P < 0.001$; treatment × period, $P = 0.21$; treatment × day, $P = 0.007$; period × day, $P = 0.80$; treatment × day × period, $P = 0.02$). Means within a period and day with different superscripts differ (*$P \leq 0.05$; **$P \leq 0.10$; and > 0.05).

P1 and P2 (Fig. 4). The TUB steers spent more ($P \leq 0.05$) time consuming mineral per day than LM steers for 3 of 7 d during P1, which increased to 6 of 7 d during P2 (Fig. 4). Additionally, TUB steers had a numerically greater duration of mineral intake per day than LM steers for all remaining days in P1 and P2. The variation in the duration of mineral intake per day remained similar across P1 (CV = 97%) and P2 (CV = 98%) for LM steers, whereas the variation decreased in TUB steers from P1 (CV = 139%) to P2 (CV = 104%).

Finally, there was a treatment × day × period ($P < 0.001$; Fig. 5) effect on the duration of mineral intake per bunk visit for P1 and P2. The

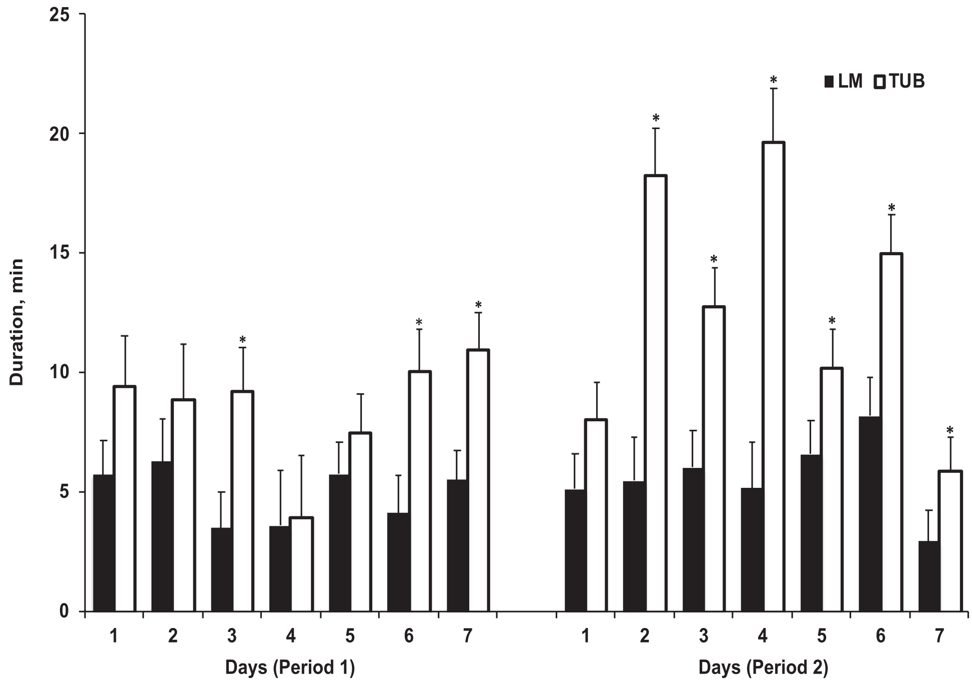

Figure 4. Treatment, day, and period effects on average duration of mineral intake per day (least squares means ± SE) for steers with free-choice access to either a salt-based loose mineral (LM, n = 22) or low-moisture molasses-based tub mineral (TUB; n = 20) during two data collection periods (treatment, $P < 0.001$; period $P = 0.02$; day, $P = 0.003$; treatment × period, $P = 0.11$; treatment × day, $P = 0.07$; period × day, $P < 0.001$; treatment × day × period, $P = 0.003$). Means within a period and day with different superscripts differ (*$P \le 0.05$).

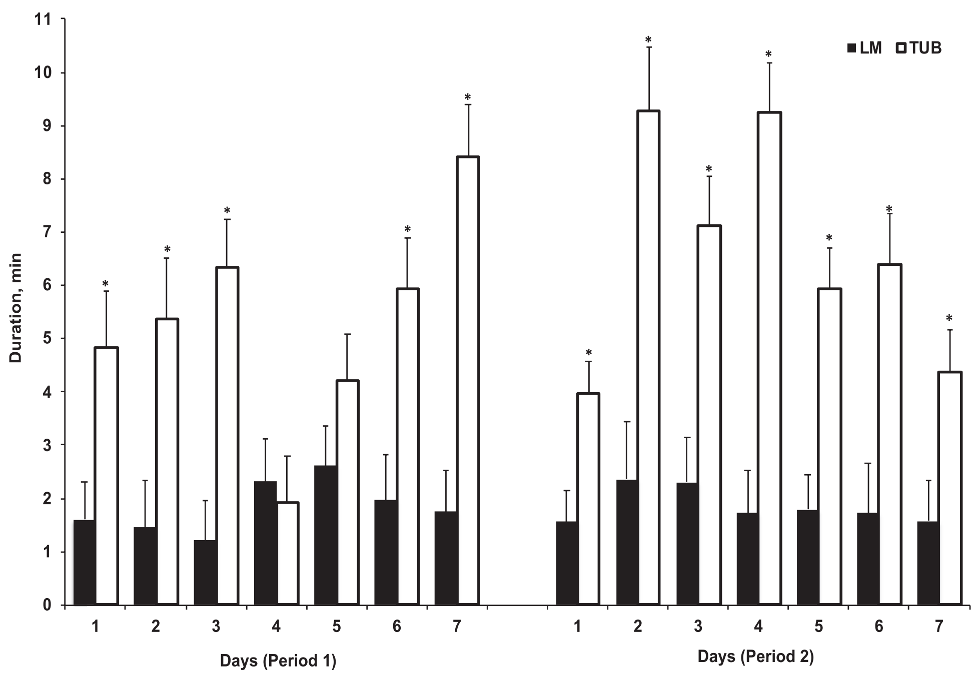

Figure 5. Treatment, day, and period effects on average duration of mineral intake per bunk visit (least squares means ± SE) for steers with free-choice access to either a salt-based loose mineral (LM, n = 22) or free-choice low-moisture molasses-based tub mineral (TUB; n = 20) during two data collection periods (treatment, $P < 0.001$; period $P = 0.24$; day, $P = 0.03$; treatment × period, $P = 0.22$; treatment × day, $P = 0.04$; period × day, $P < 0.001$; treatment × day × period, $P < 0.001$). Means within a period and day with different superscripts differ (*$P \le 0.05$).

average duration of mineral intake per bunk visit was greater ($P \le 0.05$) for TUB than LM steers for 5 of 7 d during P1, which increased to 7 of 7 d during P2. Similar to the duration of mineral intake per day, the variation in the duration of mineral intake per bunk visit remained comparable for LM steers from P1 (CV = 99%) to P2 (CV = 93%), while the variation decreased from P1 (CV = 155%) to P2 (CV = 106%) for TUB steers.

Animal Performance and Weather Correlations

The BW were not different between LM and TUB steers for both the initial ($P = 0.56$; 407 ± 13 kg; 396 ± 13 kg) and final BW ($P = 0.28$; 435 ± 12 kg; 415 ± 13 kg), respectively. However, ADG was greater ($P \leq 0.05$) for LM (0.73 ± 0.05 kg) than TUB (0.58 ± 0.05 kg) steers over the 38 d mineral intake period.

There were no ($P > 0.05$) correlations of tangible importance between daily mineral intake, number of bunk visits per day, mineral intake per bunk visit, duration of mineral intake per day, and duration of mineral intake per bunk visit with any weather variable evaluated. Across the 14 test days, the daily value (mean ± SD) for mean temperature was 19.6 ± 2.9°C, minimum temperature was 9.2 ± 3.3°C, maximum temperature was 29.7 ± 3.3°C, mean humidity was 43.3 ± 8.0%, and maximum humidity 76.1 ± 8.1%, while total precipitation was 0.20 cm over 2 d.

DISCUSSION

The significant lower daily bunk attendance for TUB compared with LM steers during all periods was unexpected. The LM steers appeared to have no issues adapting to the GrowSafe System by the end of the AP, but this was not the case for TUB steers. It is unclear whether TUB steers were having problems adapting to the bunks or just had less frequent bunk attendance. Although, of the TUB steers that attended the bunk and consumed mineral, every steer visited the bunk and consumed mineral at least once within each of the three periods mineral intake was evaluated. Therefore, TUB steers were accessing feed bunks but just less frequently than LM steers, which is reflected in the decreased number of bunks visits per day for TUB compared with LM steers during all three periods. Additionally, the TUB treatment did not receive any salt throughout the three experimental periods. This could have had a negative effect on bunk attendance and daily mineral intake of the TUB as salt can stimulate feed and mineral intake (Greene, 2000; Berger, 2006). The intake limiter in the TUB could also be modifying bunk attendance patterns by how often steers needed to attend the bunk to consume mineral. It is also possible that consuming mineral from a tub placed inside the GrowSafe bunk was a novel experience that modified steer behavior and subsequently bunk attendance. Livestock can have an aversion to either novel feeds or feeders, which gradually decreases over time as they become more acclimated to either the feed or feeders (Chapple and Lynch, 1986; Launchbaugh, 1995). This is supported by the observation that TUB steers had similar bunk attendance compared with LM steers during P2. Moreover, bunk attendance was only greater for 2 of 7 d for LM compared with TUB steers during P2, which was considerably less than the 6 of 7 d during the AP, and 5 of 7 d during P1. Most studies using the GrowSafe System to monitor mineral intake utilized a 7 to 10 d adaptation period before standard data collection (Cockwill et al., 2000; Garossino et al., 2003). The length of the adaptation period in the current study appears appropriate for LM steers but not TUB steers. There has been no published research identified utilizing the same low-moisture molasses-based tub mineral used in the current study. Consequently, further research is warranted to determine the appropriate length of an adaptation period when using the GrowSafe System to evaluate intake behaviors with this low-moisture molasses-based tub mineral.

During the AP, daily mineral intake was significantly greater for LM than TUB steers. However, throughout P1 and P2, daily mineral intake was similar between LM and TUB steers. It also appears that approximately 1 wk was needed for daily mineral intake to normalize between treatments despite the different intake limiters between treatments. For LM steers, there was a 34% reduction ($P < 0.05$) in daily mineral intake from the AP to P1, which was likely due to the addition of 20% more salt to the base mineral mix during the AP. In contrast, TUB steers had a 23% increase in daily mineral intake from the AP to P1. Addition of salt to a free-choice loose mineral results in decreased mineral intake (Harvey et al., 1986; Cockwill et al., 2000) and is a common practice used to control and limit free-choice loose mineral intake in livestock.

Even though there were no treatment differences in the average amount of mineral consumed per day across P1 and P2, there were intake differences across days throughout the experiment as there was a 139-g difference between the lowest and highest average daily mineral intake. The large fluctuations in mineral consumed on either a daily or per bunk visit basis are illustrated by the substantial ranges in intakes presented in Table 2 for both LM and TUB treatments. Furthermore, Figure 1 illustrated the considerable variation in daily mineral intake observed within an individual steer as well as across steers within treatments. For example, in the LM treatment, there was one steer that had an average daily intake of 807 ± 404 g during P1 and P2, which was 420 g above the mean intake for all LM steers. Although, the presence of a similar "super-consumer" was not observed in the TUB treatment. Cockwill et al. (2000) concluded that large variations observed in daily mineral intake resulted from large animal-to-animal intake variation, which is certainly the case for LM and TUB steers. Moreover, variations in individual animal intake in the present experiment were probably influenced by the number of bunks visits per day as well as the duration of these visits. For example, LM steers had more bunk visits per day but spent less time consuming the mineral. Whereas, TUB steers have fewer bunk visits per day but spent more time consuming the mineral. Consequently, individual daily mineral intake is influenced by the amount of bunk visits per day as well as the durations of these visits, which are different between mineral delivery methods. Although, it should be noted that intake of the two mineral supplements used in this experiment may not be reflective of consumption of other salt-based loose mineral mixtures or solid mineral blocks offered in a similar manner. Furthermore, it is unclear how the GrowSafe System with a configuration like the one used in present experiment where only one animal can consume mineral at a time may have altered animal behaviors associated with mineral consumption compared with production settings where multiple animals have the opportunity to consume mineral simultaneously. Further research is required to address these issues.

Variation in daily mineral intake in the current study agrees with reports in grazing steers (Garossino et al., 2003; Manzano et al., 2012) and suckled cows (Cockwill et al., 2000) using the GrowSafe System to monitor loose mineral intake. Similar results have also been reported in cattle consuming block-based minerals (Weber et al., 1992; Garossino et al., 2003) using different monitoring techniques. It also emphasizes the considerable variation in mineral intake that exists between mineral types, within an animal, and among animals over time. Variation in daily mineral intake is the greatest problem to overcome when providing minerals free choice (Greene, 2000). There are numerous factors that can affect intake of free choice minerals including percent salt or intake modifiers in mineral, forage type and availability, mineral content of forage and drinking water, daily temperature fluctuations, palatability of mineral mixture, and access/distance from water (McDowell, 2003). How these aforementioned factors interact with animal behavior to modify mineral intake is a research area that is still largely unexplored.

An interesting observation resulting from this research was the presence of cyclic patterns for the amount of mineral consumed per bunk visit per day and the length of time it took to consume the mineral, which are more pronounced in TUB than LM steers. A general consumption pattern consisted of a peak in mineral intake followed by one to several days of decreased intake, which is similar to an intake pattern reported by Manzano et al. (2012) in grazing steers fed a salt-based loose mineral with intake tracked with the GrowSafe System. Moreover, the magnitude in difference between high intake days and low intake days appears to be greater in TUB compared with LM steers, which is likely due to fact that TUB steers have fewer visits to the bunk per day and were consuming more mineral per bunk visit than LM steers. Peaks in average mineral intake per bunk visit appears to be associated with greater bunk attendance in the TUB steers but not the LM steers, which is not surprising since daily bunk attendance was greater than 90% across P1 and P2 for LM steers. What factor(s) are driving the cyclic patterns in mineral intake is unclear. Although, our results and those of others (Bell et al., 1981; Valk and Kogut, 1998) suggest that physiological feedback mechanisms may be functioning on a daily basis to regulate mineral intake. Furthermore, the manner in which the feedback mechanisms are operating, both physiologically and quite possibly behaviorally, is probably affected by the different intake limiters between the LM and TUB treatments.

As previously indicated, TUB steers had fewer bunk visits per day but spent more time at the feed bunk consuming more mineral per bunk visit compared with LM steers. This is likely due to TUB steers having to spend more time licking the solid mineral from the tub while LM steers were able to consume a similar amount of loose mineral from the bunk in a shorter period of time. Moreover, as the amount of mineral available in the tub decreases over time, it is possible that the mineral either develops a harder texture and(or) the surface of the tub becomes concaved instead of flat, which may require more licking by steers over a longer period of time to consume the same amount of mineral. Accordingly, the method of mineral delivery appears to impact the behavior of how steers consumed mineral.

There was a 56% increase in the duration of mineral intake per day from the AP to P2 for TUB steers even though there were no significant changes in the number of bunk visits per day over that time period. One reason for this increase was probably due to more TUB steers starting to consume mineral by P2. With more steers attending the feed bunk and consuming mineral, it probably changed the behavior of when steers within the group attended the bunk and the time spent consuming mineral. Moreover, TUB steers may have become more acclimated to the feed bunk, resulting in greater durations of mineral intake as concluded by Cockwill et al. (2000) in grazing heifers. Interestingly, Kendall et al. (1983) reported that sheep fed block supplements had greater intake when blocks were fed individually compared with a group-fed scenario. Therefore, lack of competition at the feed bunk could be modifying intake behaviors of TUB steers and making it easier for steers to consume mineral for longer periods of time. When only one animal has access to the feed location at a time like the present experiment, intake behaviors of other animals in the group are probably being modified. Hence, cattle behavior in a grazing situation where multiple animals have access and opportunity to consume mineral concurrently from a feeder may differ from our results.

The ADG was greater for LM than TUB steers during the treatment period. Although, caution should be used in drawing conclusions as these results only represent a 38-d period. One could speculate that the greater ADG of LM compared with TUB steers might be associated with a more consistent level of mineral intake and more LM steers consuming mineral on a daily basis compared with TUB steers. A considerable amount of research supports the importance of balanced mineral nutrition for adequate performance of cattle (see Spears and Weiss, 2014). Adding extra salt to cattle diets increases water consumption compared with cattle not offered additional salt (Riggs et al., 1953; Berger, 2006). Consequently, the added salt in the LM treatment may have increased daily water intake and potentially water retention compared with the TUB treatment with no added salt, which may have influenced the greater ADG in LM compared with TUB steers.

The direct effect of environmental factors like temperature and humidity on mineral consumption is inconclusive. Manzano et al. (2012) reported no effect of temperature on daily mineral intake during the spring to fall in beef cattle, similar to the present study that was conducted in the summer. In contrast, Weber et al. (1992) reported that intake of mineral in block form was influenced by weather in beef cattle.

In conclusion, mineral intake was highly variable among animals, within an animal, during a day, and across days for steers grazing pasture receiving free-choice access to either a salt-based loose mineral or low-moisture molasses-based tub mineral. The mineral delivery methods used in the present study altered individual animal intake as well as feeding behaviors. Once the adaptation period effects were accounted for, average daily mineral intake was similar between TUB and LM steers even though TUB steers had less bunk attendance and fewer bunk visits per day to consume mineral than LM steers. Furthermore, there were significant differences in feeding behaviors among treatments with TUB steers spending significantly more time-consuming mineral than LM steers. These results provide additional insight into how animal behavior contributes to the difficulty in controlling daily mineral intake in either meeting or exceeding trace mineral requirements of grazing cattle. Over consumption can lead to excess mineral usage with potential for mineral toxicity and an increased cost to producers. Future research will need to focus on how to reduce variation in free-choice mineral intake by individual animals when using different mineral delivery methods.

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