A pilot study investigating consumption patterns of chlortetracycline-medicated mineral supplement offered free-choice to beef cows on pasture

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Abstract
The study objective was to describe the consumption of chlortetracycline (CTC)-medicated mineral offered free-choice to beef cows on pasture in Mississippi. Gestating commercial beef cows (n = 103) housed on pasture were divided into 3 pasture groups. Each pasture group had access to portable, self-contained feeding units that recorded cow identification by radio frequency identification tags, feeding time and mass consumed per feeding event. After feeding a 50:50 dried distillers grain (DDG)/NaCl mixture in the units for a 27-day adaptation period, the DDG/NaCl mixture was replaced by a commercial granular mineral containing CTC (6,172 mg CTC/kg mineral). Medicated-mineral intake was monitored for 46 days from 7/5/2022 to 8/19/2022. Associations between the independent variables (i.e., cow age, pasture group, etc.) and the dependent variables (i.e., total kilograms of CTC-medicated mineral supplement consumed during the trial period, total days the feeding unit was visited per cow during the trial period, etc.) were tested using linear regression models. Statistical significance was set a priori at alpha = 0.05. On average, 27% of cows consumed mineral each day. During the 46-day trial period, the average dose of CTC received per cow was 0.53 mg CTC/kg body weight/day, and 92/103 cows consumed less than the label-indicated 1.1 mg/kg/day dose during the trial period. As cow age increased, feeder visits became less frequent ($P < 0.001$) and total consumption of CTC-medicated mineral declined ($P < 0.001$). In this study, feeding CTC-medicated mineral in a free-choice manner did not ensure cows on pasture consumed the label-indicated CTC dose of 1.1 mg/kg/day.

Key words: beef cattle, chlortetracycline, mineral, SmartFeed, bovine anaplasmosis

Introduction
Dietary minerals such as Ca, P, Na, Mg, Cu and Zn are essential to the normal physiologic, immunologic and reproductive processes of livestock.[1,2] In many food animal production industries (e.g., commercial feedlot, dairy, swine and poultry operations), the dietary mineral requirements of animals are met by incorporating mineral supplements into a total mixed ration.[3] This feeding method ensures individuals consume a specified amount of dietary mineral during each feeding event. Unlike other confinement-based food animal industries, the beef cow-calf industry is primarily pasture-based and depends on forage as the primary source of nutrients. Forage mineral content varies depending on factors such as geographic location, forage species, forage maturity, prior fertilizer application and soil pH, making supplemental feeding of these dietary elements necessary on many cow-calf operations.[1] Hand-feeding mineral supplements is often not practical due to labor and cost constraints on pasture-based cow-calf operations; thus, free-choice mineral supplementation is commonly used as a convenient alternative.[2] Although convenient, consumption of mineral supplement when offered free-choice is voluntary, and precludes the ability to ensure adequate individual animal daily intake.

Historically, free-choice mineral supplements have been used as a vehicle to deliver a variety of medications to cattle on pasture.[3-5] However, factors such as forage dry matter content, season of the year, concurrent use of other protein-energy supplements, individual animal production status (i.e., maintenance, growth, gestation, lactation), salinity of drinking water, palatability of mineral and physical form of mineral (i.e., block vs. loose granular form) all affect consumption of mineral supplements by cattle on pasture.[1,6] Thus, these factors represent barriers to consistent intake of medications delivered in free-choice mineral supplements as well. Chlortetracycline (CTC) is one such compound that is commonly delivered to cattle via mineral supplements. Chlortetracycline, a tetracycline antimicrobial compound, is approved by the U.S. Food and Drug Administration (FDA) for inclusion in beef cattle feeds, mineral mixes and mineral blocks "for the control of active infection of bovine anaplasmosis (BA) caused by *Anaplasma marginale* that is susceptible to chlortetracycline."[7] Bovine anaplasmosis causes substantial economic loss in the U.S. beef cow-calf industry each year, and leads to the use of a meaningful amount of medically-important antimicrobials in the cow-calf sector of the beef industry.[8] Chlortetracycline delivered in-feed or in medicated mineral is one of the most commonly used antimicrobial-based methods of BA control for cattle on pasture.[8] The United States Department of Agriculture (USDA) National Animal Health Monitoring System's (NAHMS) Beef 2017 study, found 4.4% of all beef cow-calf operations used CTC in feed, mineral mixes or mineral blocks for BA control. Of these, 82.0% provided CTC through free-choice loose mineral (70.8%) or a medicated mineral block (11.2%).[9] Both of these feeding methods preclude control of CTC intake, potentially exposing cattle to inappropriate doses over time. Furthermore, there are currently no restrictions on the duration of use of CTC in feed or mineral products for BA control, provided the producer maintains a valid Veterinary Feed Directive (VFD).[7] Evidence supporting the use of feeding CTC-medicated mineral in a free-choice manner for control of morbidity and mortality associated with BA is lacking, and antimicrobial stewardship concerns have brought this practice under scrutiny.

Previous researchers have identified tremendous variation in individual animal mineral intake in pasture-based systems. In a 1992 study, researchers found individual animal daily mineral consumption for grazing Holstein steers to range from 60 to 330 g per day.[10] In a 1996 study, researchers reported individual daily mineral intake for beef steers to range from 50 to 300 g per day.[2] A 1997 study, Cockwill, McAllister and Olson, found individual animal daily mineral supplement intake to vary from 0 to 974 g per day in 69 lactating beef cattle, however, this study was limited to a 13-day period.[5] Limitations exist to the generalizability of measured daily beef or dairy steer mineral intakes to those of beef cows on pasture, since factors such as production status (i.e., gestating or lactating) differ between these populations. Additionally, prior research measuring individual daily mineral intake is limited to short lengths of time, without respect to seasonal forage variation or changes in cow nutritional and production status. In a 2020 study, Reppert et al. measured plasma CTC concentrations of cows fed one of 4 different FDA-approved free-choice CTC-medicated minerals on a monthly basis, and found that formulation (i.e., concentration of CTC, as well as block vs. granular mineral form) and time (i.e., month of sampling) affected monthly plasma CTC concentrations in cows.[11] In a 2021 study, McCarthey et al. found mean intake of mineral supplement offered free choice to cattle on native pasture to range from 125.4 g/d in high-consuming cows to 33.5 g/d in low-consuming cows.[12] To the authors knowledge, no studies have evaluated individual animal daily intake of CTC-medicated mineral supplement fed in a free-choice manner to determine daily individual CTC dose received. Additionally, research investigating the impact of cow age on daily mineral consumption is limited. Therefore, the objectives of this study were to describe the temporal consumption patterns of CTC-medicated mineral supplement offered free-choice to beef cows on pasture and test the effect of cow age on CTC-medicated mineral supplement intake.

Materials and methods

This study was conducted with the approval of the Institutional Animal Care and Use Committee (IACUC) protocol #22-092 through the Office of Research Compliance and Security at Mississippi State University.

Animals

This study took place at the Mississippi Agricultural and Forestry Experiment Station (MAFES) Prairie Research Unit (PRU) from June 8, 2022, to August 19, 2022. A total of 103 gestating Angus-Charolais cross commercial fall-calving cows housed on native grass pasture were used in this study. All pastures used in this study consisted of abundant mixed perennial grasses including tall fescue (*Lolium arundinaceum*), bahiagrass (*Paspalum notatum* Flugge), dallisgrass (*Paspalum dilatatum*) and common bermudagrass (*Cynodon dactylon*). Cattle used in this project ranged from 3 years to 17 years of age, with a mean age of 6 years (SEM = 0.31). Body weight at day 0 ranged from 360-695 kg, with a mean of 507 kg (SEM = 7.8), and BCS at day 0 ranged from 4 to 6 with a mean of 4.9 (SEM = 0.07). Prior to the beginning of the study (day -28), body weights and body condition scores (BCS) were collected on all cattle. Cattle were stratified by age, body weight and body condition, and randomly allocated into 3 groups using a random number generator, such that each group had relatively even distributions of cattle at different ages, body weight and BCS[a]. A total of 36, 38 and 29 head were allocated to groups 1, 2 and 3, respectively, and the cows were maintained in these 3 groups for the duration of the study. The number of cows per group was determined based on forage and pasture availability at the research unit, with group 3 being smaller by necessity of forage and pasture space. As part of the normal summer grazing management practices at MAFES PRU, groups 1 and 2 were rotated through 10-hectare pastures approximately every 25 days, while group 3 remained on one pasture (40-hectares) for the duration of the study. In addition to ear tags containing herd-level identification, all cows were equipped with an electronic identification tag containing a passive transponder that provided the unique individual animal identification used in this study[b]. The calves born in the fall of 2021 to the cows used in this study had been weaned and removed on March 15, 2022, and the fall calving season was due to begin on August 16, 2022.

Equipment

Each group had access to a portable, self-contained, solar-powered feeding unit with 2 stainless steel feed bins (79 × 71 × 86 cm) per unit (i.e., SmartFeed units)[c]. These units have been described and validated as intake measurement tools elsewhere.[12,13] Each feed bin was suspended on 2 load cells which allowed the mass of the contents of each bin within the unit to be measured. Each feed bin was also equipped with radio frequency identification (RFID) readers to record the individual animal identification of cattle when consuming supplement from the feed bin. The adjustable metal framework surrounding each feed bin limited access to 1 animal per feed bin at a time, thus 2 animals at a time could consume supplement from each unit.

Data collection

The SmartFeed units were placed near water sources in each pasture. A 27-day adaptation period began on June 8, 2022 (day -27) and concluded on July 4, 2022 (day 0), during which a 50:50 dried distillers grain (DDG) mixed with NaCl diet was provided in each feed bin of each SmartFeed unit in a free-choice manner. During the adaptation period, all cattle were fed a commercially available granular mineral containing CTC at a concentration of approximately 6,172 mg CTC/kg mineral (2.8 g/lbs.)[d] in a round, 3-bin self-feed mineral feeder with a rubber covering to shield the contents from rain. This mineral feeder was located near the SmartFeed units in each pasture. Beginning on July 5, 2022 (day 1) and extending through the end of the trial period on August 19, 2022 (day 46), the conventional self-feed mineral feeder was removed, and the 50:50 DDG/NaCl mixture within each bin of each SmartFeed unit was replaced with the same commercially available granular mineral containing CTC that had previously been supplied in the conventional mineral feeder. Table 1 displays the composition of the mineral supplement provided during both the adaptation and trial periods. The feeding units were monitored daily to ensure an adequate amount of CTC-medicated mineral was present in the feeders to provide all cattle in the pasture with the label-indicated dose of 1.1 mg CTC/kg body

Table 1: Nutrient composition of the mineral supplement provided to cattle during both the adaptation and trial period. Values represent company guaranteed analysis as reported on the product label. Chlortetracycline was present in the supplement at a concentration of 2.8 g/lb. (6,172 mg CTC/kg mineral supplement).

Nutrient	Min	Max
Macrominerals (%)		
Calcium	16.2%	19.44%
Phosphorus	4%	N/A
Salt (NaCl)	22.5%	27%
Magnesium	1.0%	N/A
Potassium	0.1%	N/A
Microminerals (ppm)		
Manganese	4,800 ppm	N/A
Cobalt	18 ppm	N/A
Copper	1,200 ppm	N/A
Iodine	60 ppm	N/A
Selenium	27 ppm	N/A
Zinc	3,600 ppm	N/A
Vitamins (IU/lb.)		
Vitamin A	150,000 IU/lb.	N/A
Vitamin D3	15,000 IU/lb.	N/A
Vitamin E	150 IU/lb.	N/A

weight/day. The data acquisition system in each SmartFeed unit recorded RFID tag number, bin number and the beginning and end mass of feed in the bin for each feeding event. The final dataset included total feed consumed per day for each cow during both the adaptation period and the trial period.

Data analysis

Cattle feeding and intake data from each SmartFeed unit was compiled into spreadsheet software where data summarization and descriptive statistics were performed[a]. Inferential analysis was performed using statistics software[e]. Outcomes of interest included 1) total kilograms of DDG/NaCl diet consumed during adaptation period, 2) total days the feeding unit was visited per cow during the adaptation period, 3) total kilograms of CTC-medicated mineral supplement consumed during the trial period, 4) total days the feeding unit was visited per cow during the trial period, and 5) total number of days when cattle consumed at least the label-indicated CTC dose (i.e., 1.1 mg CTC per kg of body weight). Outcomes were modeled using linear regression (PROC MIXED). Visual inspection of conditional residuals was used to assess if model assumptions of linearity, homoscedasticity and normality of residuals were met. Cow age in years, cow body weight taken on day 0, cow BCS taken on day 0, and pasture group were tested as fixed effects in each model. The LSMEANS statement and Tukey's HSD test were used to evaluate differences in least squares means among differing levels of explanatory variables with more than 2 levels (i.e., pasture group). If pasture group was not significant as a fixed effect, it was included in the model as a random variable. All models were assembled using manual forward variable selection. Visual assessment of scatterplots, as well as calculated coefficients of determination for the relationship between age and outcomes of interest revealed a probable quadratic relationship, therefore age was tested as a quadratic variable in all models. The quadratic age variable was retained in models where model fit, as measured by Akaike's Information Criterion (AIC) values, was improved by modelling age as a quadratic variable. Statistical significance for all steps in the modelling process was defined a priori as alpha = 0.05.

Results

Adaptation period

During the adaptation period, all cattle visited the SmartFeed units and consumed some amount of the DDG/NaCl adaptation diet. On average, 76.3% of cattle across all pasture groups consumed any amount of DDG/NaCl diet per day during the adaptation period. Across all pasture groups, the average 27-day total intake of the DDG/NaCl diet was 7.84 kg per cow (SEM = 0.43), the minimum total intake was 2.57 kg, and the maximum total intake was 23.66 kg. Figure 1 displays the distribution of total kilograms of the DDG/NaCl diet consumed during the adaptation period. The average daily intake of the DDG/NaCl adaptation diet across all pasture groups was 0.29 kg (SEM = 0.02) per cow per day. Figure 2 displays average daily intake of the DDG/NaCl diet during the 27-day adaptation period across all pasture groups. The crude data describing age of cow in years plotted against total amount of DDG/NaCl diet consumed during the adaptation period is displayed in Figure 3. Age of cow and pasture group were associated with the number of days any amount of DDG/NaCl diet was consumed during the 27-day adaptation period; however, BCS and body weight were not (Table 2). The crude data describing age of cow in years plotted against the number of days any amount of DDG/NaCl diet was consumed during the adaptation period is displayed in Figure 4. Pasture group was associated with the total amount of DDG/NaCl diet consumed during the adaptation period, however, age of the cow, body weight and BCS were not (Table 3).

Trial period

During the 46-day trial period, an average of 27% of cows across all 3 pasture groups visited the mineral feeder daily and consumed any amount of CTC-medicated mineral (Figure 5). The average amount of CTC-medicated mineral supplement consumed per cow per day was 40.8 g (0.09 lbs.). One individual did not consume any mineral supplement during the entire 46-day trial period, but visited the feeding unit on 13 different days during the adaptation period, consuming a total of 2.57 kg of DDG/NaCl diet. Conversely, one cow consumed 9.7 kg (21.3 lbs.) of CTC-medicated mineral supplement during the trial period, receiving an average daily CTC dose of 2.46 mg CTC/kg body weight/day. A frequency distribution of the total amount of CTC-medicated mineral supplement consumed per cow during the trial period is displayed in Figure 6. Using cow body weights collected prior to the beginning of the adaptation period (day -28), the average daily CTC dose received per cow during the trial period was 0.53 mg CTC/kg body weight/day. A frequency distribution of the average daily dose of CTC per

Figure 1: Frequency distribution of total kilograms of the DDG/NaCl adaptation diet consumed during the 27-day adaptation period.

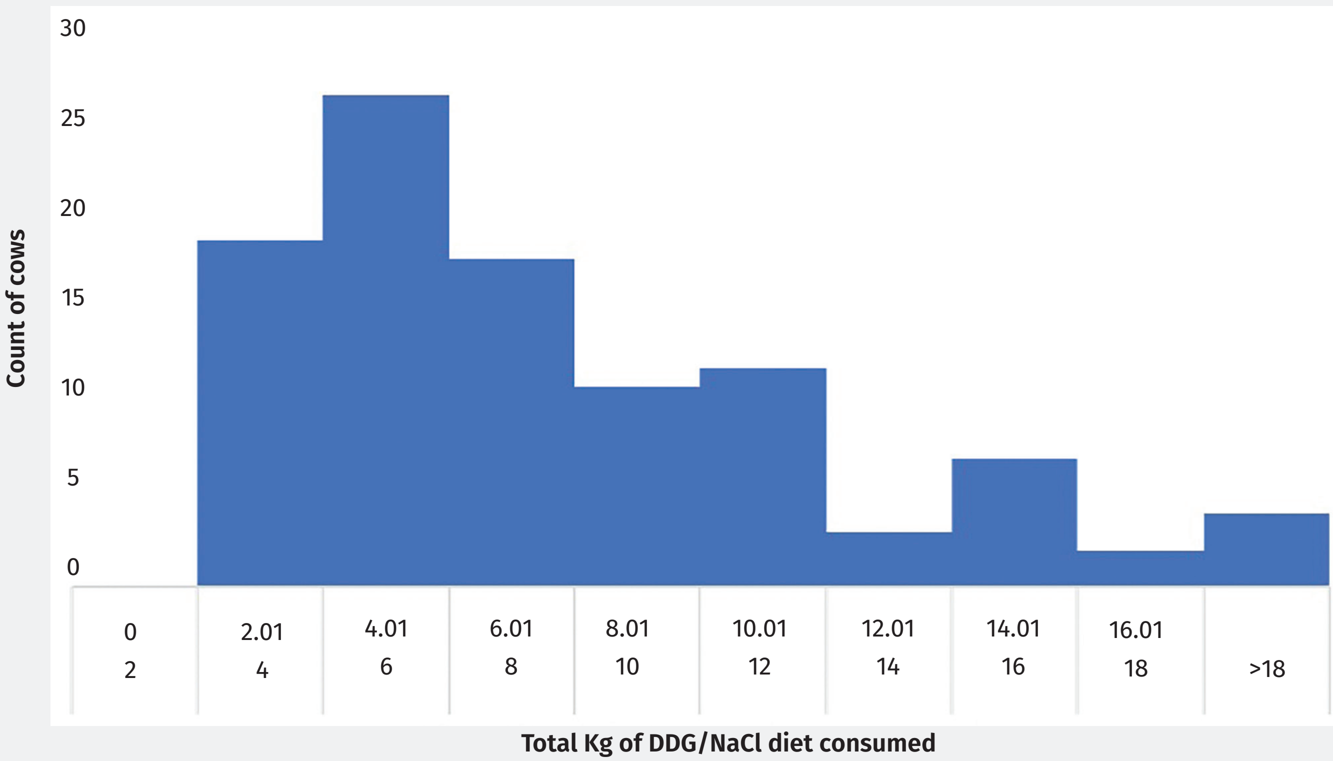


Figure 2: Frequency distribution of the average daily amount of the DDG/NaCl diet consumed (kg/day) during the 27-day adaptation period.

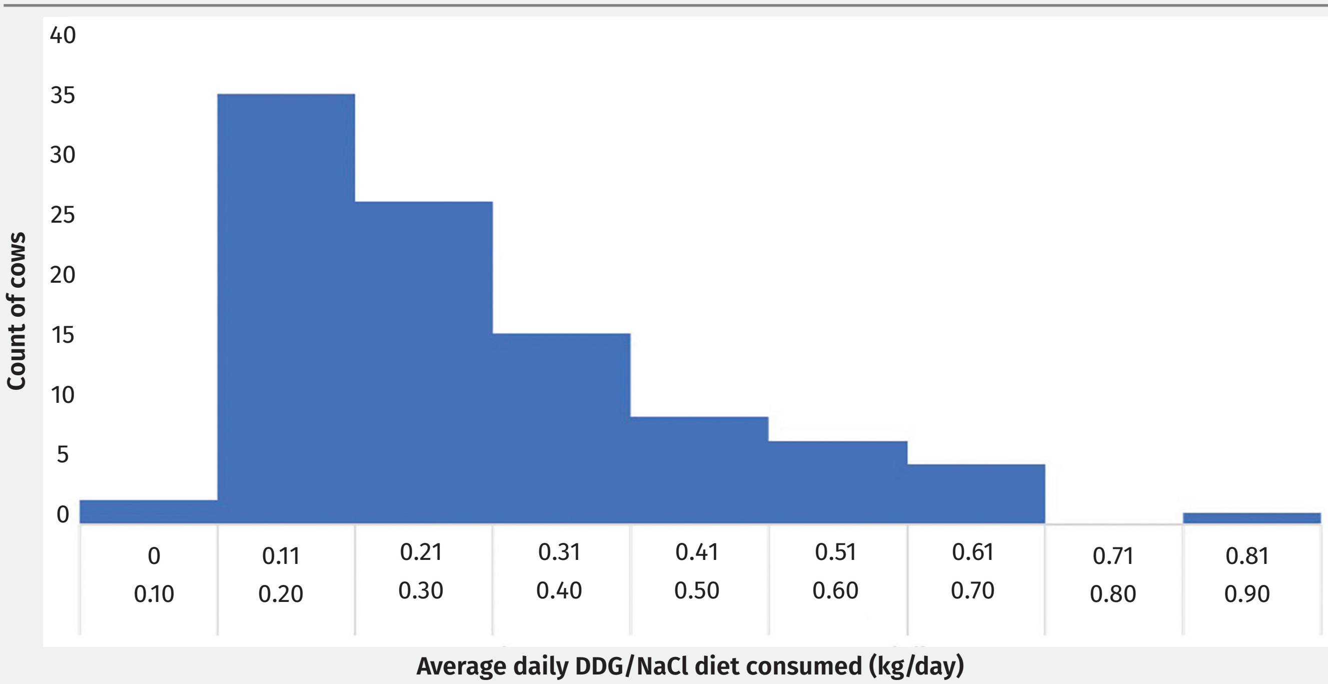


Figure 3: Scatterplot of crude data for total amount of DDG/NaCl diet consumed during the 27-day adaptation period plotted against age of cow.

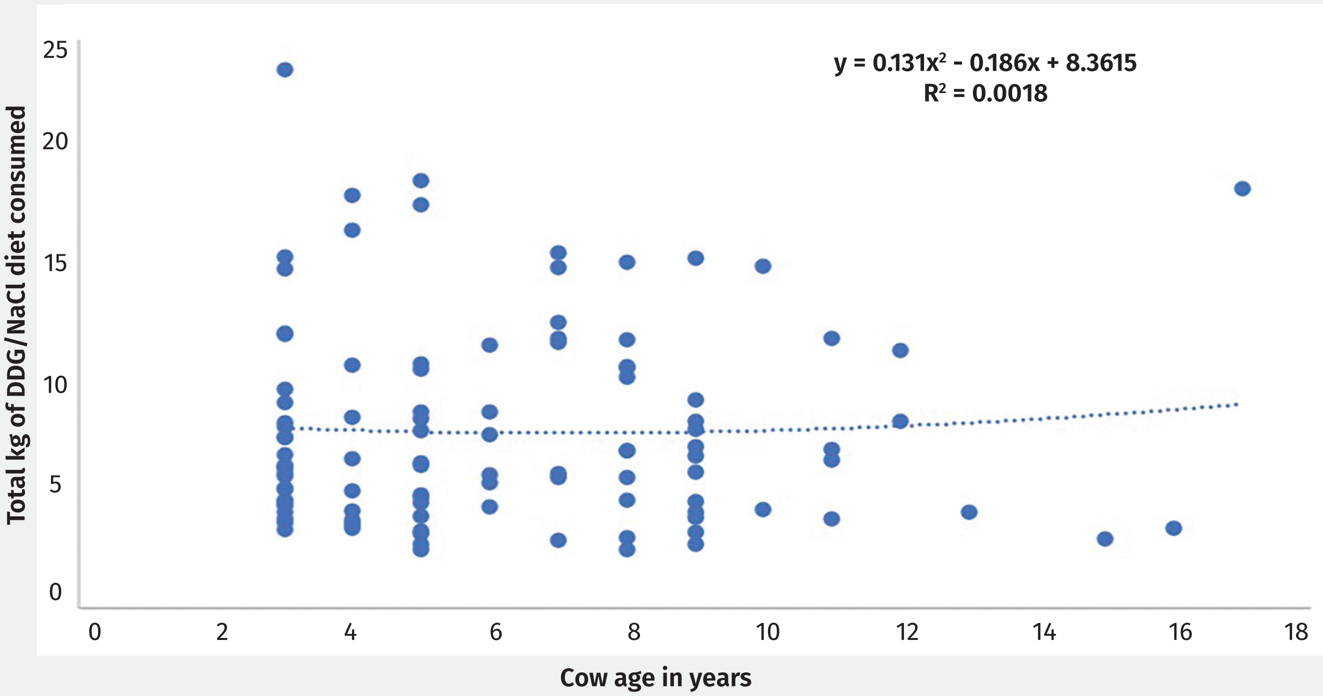


Table 2: Linear regression multivariable model results for number of days when any amount of DDG/NaCl diet was consumed during the 27-day adaptation period.

Variable	Level	Estimate	Standard error	95% C.I.		*P*-value
Intercept		21.1	0.93	19.2	22.9	< 0.001
Age		-0.34	0.10	-0.55	-0.14	0.001
Pasture group	1	-0.54	0.80	-2.12	1.04	< 0.001
	2	3.55	0.79	1.97	5.12	
	3	Ref.	Ref.			
Least squares means						
Variable	**Level***	**Estimate**	**Standard error**	**95% C.I.**		
Pasture group	1[a]	18.4	0.53	17.3	19.4	
	2[b]	22.5	0.52	21.4	23.5	
	3[a]	18.9	0.60	17.7	20.1	

* Letters denote statistical differences among group means as determined by Tukey's HSD test.

Figure 4: Scatterplot of crude data for number of days the SmartFeed unit was visited during the 27-day adaptation period plotted against age of cow.

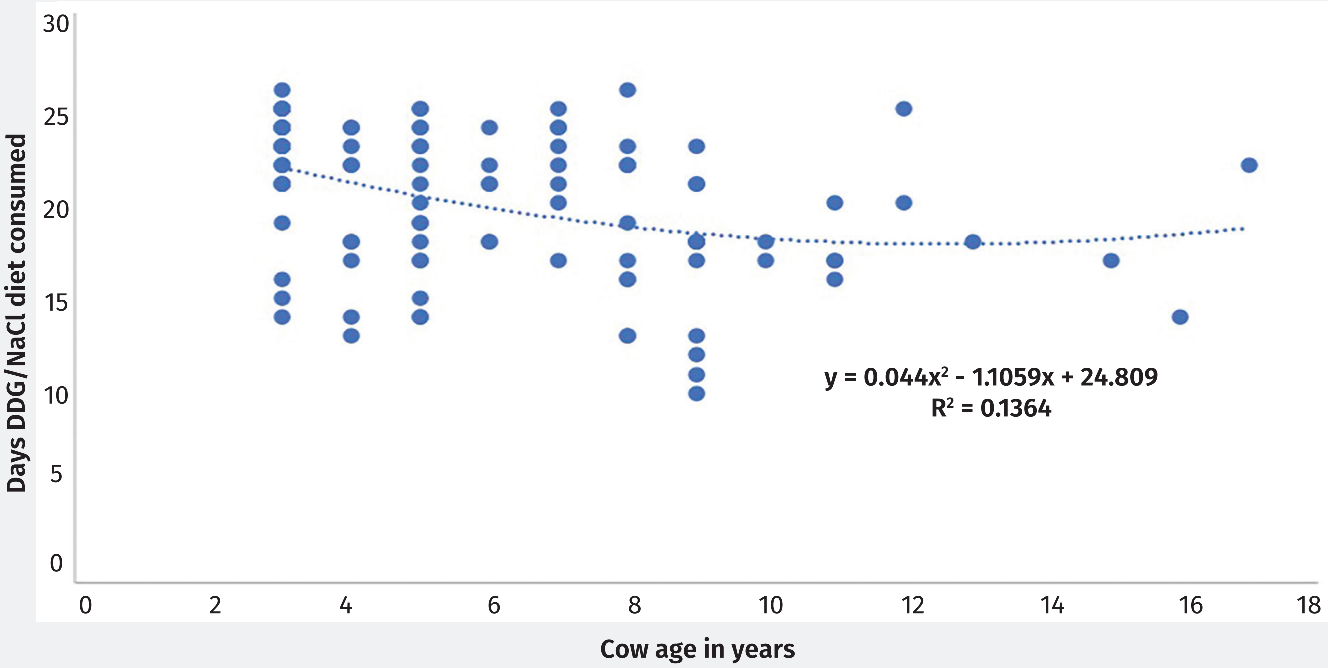


Table 3: Linear regression model results for total kilograms of DDG/NaCl diet consumed during the 27-day adaptation period. No statistically significant multivariable models were identified.

Variable	Level	Estimate	Standard error	95% C.I.		*P*-value
Intercept		7.3	0.77	5.76	8.82	< 0.001
	1	-1.12	1.04	-3.18	0.94	0.001
Pasture group	2	2.54	1.03	0.51	4.58	
	3	Ref.	Ref.			
Least squares means						
Variable	**Level***	**Estimate**	**Standard error**	**95% C.I.**		
	1[a]	6.17	0.69	4.80	7.55	
Pasture group	2[a]	9.83	0.67	8.50	11.17	
	3[b]	7.29	0.77	5.76	8.82	

* Letters denote statistical differences among group means as determined by Tukey's HSD test.

Figure 5: Proportion of cows that visited a SmartFeed unit and consumed any amount of CTC-medicated mineral during the 46-day trial period across all 3 pasture groups. The orange dotted line represents the average of 0.27.

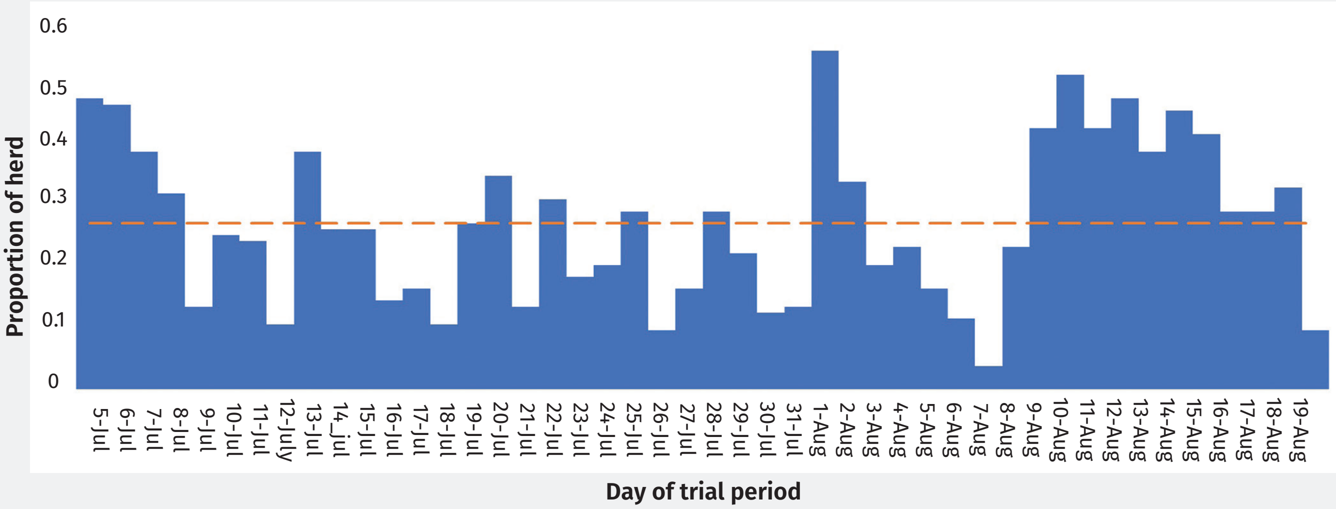
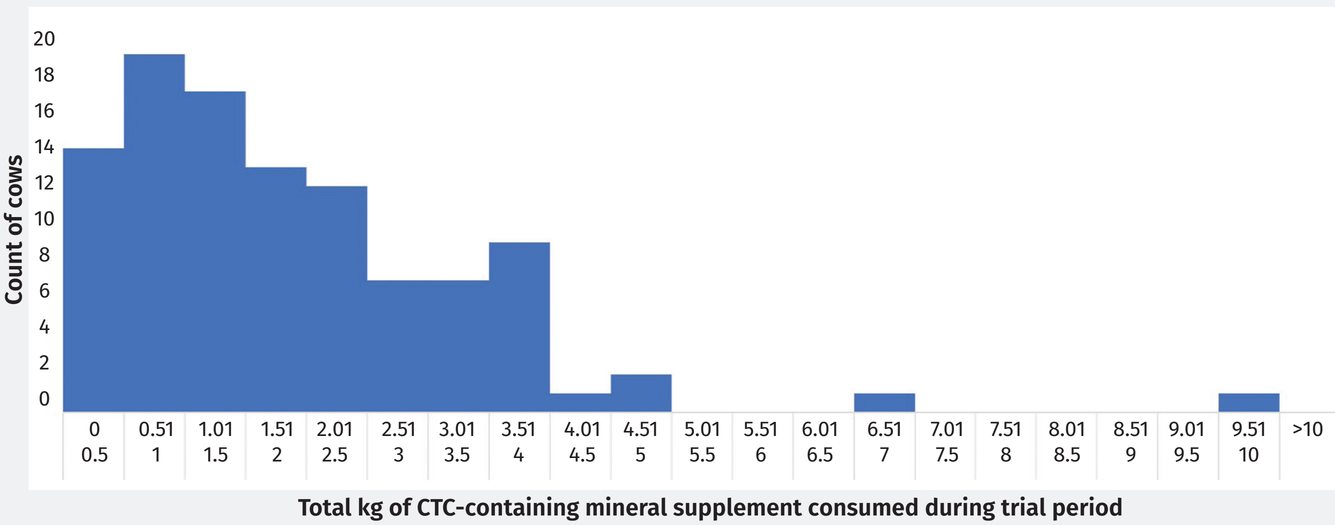


Figure 6: Frequency distribution of the total kilograms of CTC-medicated mineral supplement consumed per cow (n = 103) during the 46-day trial period.



cow (i.e., mg CTC per kg bodyweight) during the trial period is displayed in Figure 7. Overall, the mean number of consuming days (i.e., days when any amount of CTC-medicated mineral was consumed) across all cows in all pastures was 12.5 days (SEM = 0.72), while the mean number of non-consuming days across all cows in all pastures was 33.5 days (SEM = 0.72). Consuming events were defined as consecutive days when cattle consumed any amount of CTC-medicated mineral. The average length of consuming events across all cows and all pasture groups was 1.6 days (SEM = 0.09), while the average number of days between consuming events across all cows and all pasture groups was 5.9 days (SEM = 0.9). According to the manufacture's label for the CTC-medicated mineral fed during this study, each cow should consume 0.01785 lbs. (0.008 kg) of mineral supplement per 100 lbs. (45.5 kg) of body weight per day to receive CTC at a dose of 0.05 mg per lb. body weight per day (1.1 mg CTC per kg bodyweight per day). No cows consumed at least this amount of mineral every day during the 46-day trial period. Cows consumed at least the label-indicated amount of CTC-medicated mineral supplement an average of 6.4 days during the 46-day trial period, with a median of 5 days (min = 0, max = 27, SEM = 0.47). The total kilograms of CTC-medicated mineral consumed during the trial period was associated with cow age, but not with pasture group, body weight or BCS (Table 4). The total number of days any amount of CTC-medicated mineral was consumed during the trial period was associated with cow age and pasture group, but not with body weight or BCS (Table 4). Total days during the 46-day trial period when cattle consumed at least the label-indicated dose (i.e., 1.1 mg CTC per kg body weight) of CTC differed by cow age and pasture group, but not by body weight or BCS (Table 5).

Figure 7: Frequency distribution of the average daily dose of CTC received per cow (mg/kg/day) during the 46-day trial period. The 2 cows that consumed an average daily dose of CTC greater than 1.41 mg/kg/day consumed average daily doses of 2.03 and 2.46 mg CTC/kg body weight/day.

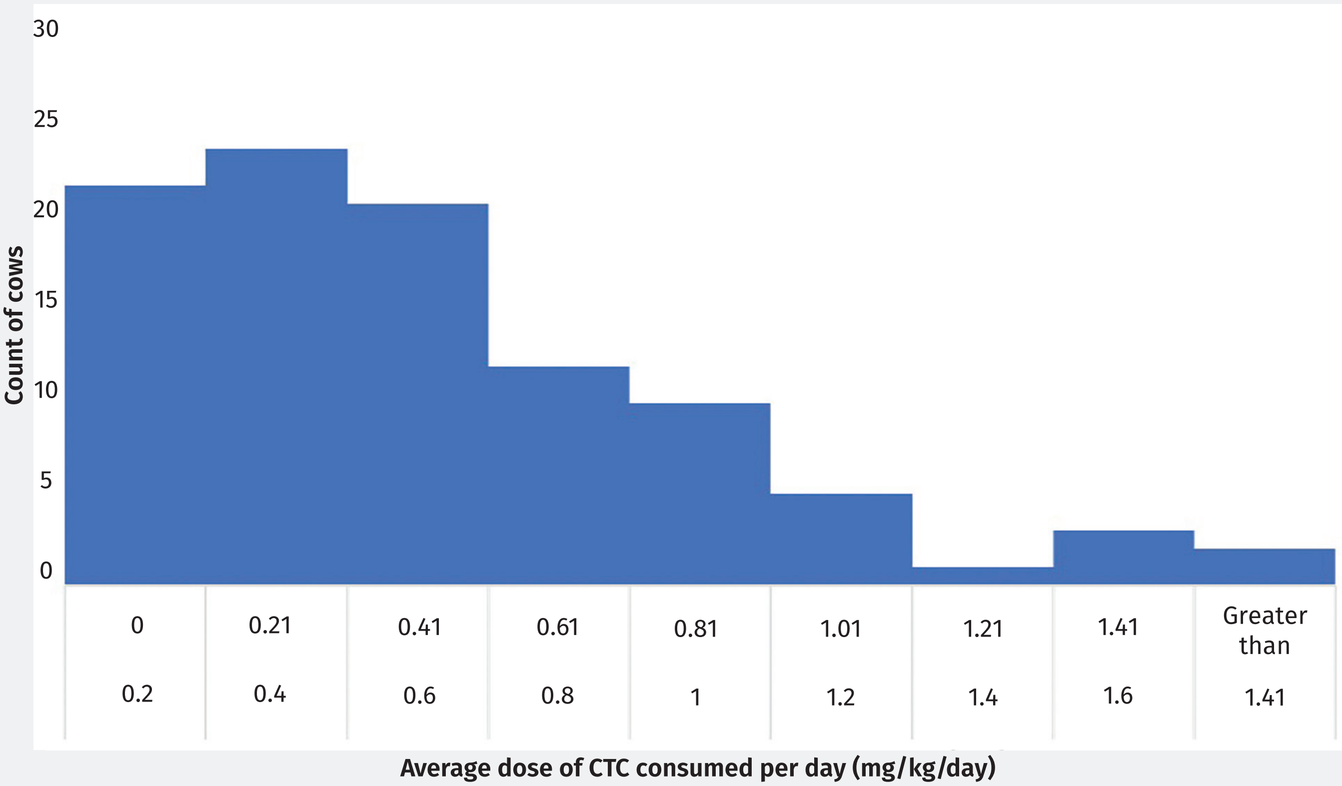


Table 4: Linear regression model results for the outcomes of 1) total kilograms of CTC-medicated mineral consumed during the 46-day trial period, and 2) total number of days when any amount of CTC-medicated mineral was consumed during the 46-day trial period. Pasture group is included as a random variable in the model of total kilograms of CTC-medicated mineral consumed.

Outcome	Variable	Level*	Estimate	Standard error	95% C.I.		*P*-value
Total kg of CTC-medicated mineral consumed	Intercept		3.15	0.32	1.8	4.5	0.011
	Age		-0.20	0.04	-0.29	-0.12	< 0.001
Total days when any amount of CTC-medicated mineral was consumed	Intercept		31.3	2.4	26.5	36.1	< 0.001
	Age		-3.2	0.6	-4.5	-2.0	< 0.001
	Age^{2}†		0.1	0.04	0.03	0.18	0.007
	Pasture group	1	-5.9	1.3	-8.5	-3.3	< 0.001
		2	-5.0	1.3	-7.6	-2.4	
		3	Ref.	Ref.			
Least squares means	Pasture group	1[a]	10.49	0.87	8.7	12.2	
		2[a]	11.42	0.85	9.7	13.1	
		3[b]	16.43	0.97	14.5	18.4	

* Letters denote statistical differences among group means as determined by Tukey's HSD test.

† Model fit improved when age modeled as a quadratic variable was included in the model.

Table 5: Linear regression model results for the outcome of total days during the 46-day trial period when at least the label-indicated dose (1.1 mg CTC per kg body weight) of CTC was consumed.

Variable	Level	Estimate	Standard error	95% C.I.		*P*-value
Intercept		17.3	1.85	13.6	21.0	< 0.001
Age		-2.03	0.48	-3.0	-1.1	< 0.001
Age^{2}[†]						0.0011
Pasture group	1	-1.92	0.99	-3.88	0.04	0.007
	2	-3.19	0.99	-5.16	-1.23	
	3	Ref.	Ref.			
Least squares means						
Variable	**Level***	**Estimate**	**Standard error**	**95% C.I.**		
Pasture group	1[a]	6.3	0.65	5.02	7.58	
	2[b]	5.02	0.64	3.75	6.3	
	3[a]	8.22	0.74	6.75	9.69	

* Letters denote statistical differences among group means as determined by Tukey's HSD test.

† Model fit improved when age modeled as a quadratic variable was included in the model.

Discussion

This study identified variation in individual animal daily intake of a CTC-medicated granular mineral supplement fed free-choice to beef cows on pasture. The observed variation in CTC-medicated granular mineral supplement consumption led to differences in the average daily dose of CTC received by each cow. In the present study, most animals voluntarily consumed less than the label-indicated amount of CTC-medicated granular mineral supplement needed to receive the label-indicated daily CTC dose of 1.1mg/kg/day (Figure 7). This pilot study provides evidence that using free-choice fed granular mineral as a vehicle to deliver CTC to cows on pasture does not ensure individual cattle will voluntarily consume an amount of mineral appropriate to receive the label-indicated daily CTC dose.

The cow-calf industry in many areas of the U.S. is predicated on grazing systems that utilize pasture forages as the primary source of nutrition for large portions of the year. When cattle are maintained in a pasture setting, hand-feeding CTC-medicated supplements is often not feasible. Thus, in the author's experience, CTC-medicated mineral products that are labeled to be hand-fed are often fed in a free-choice manner that is not consistent with the FDA definition of "hand-fed" used on medicated feed labels.[14] The FDA is aware of this issue and has stated its intent to employ a phased enforcement strategy for implementation of the final rule under Guidance for Industry #231.[15] In an attempt to mimic industry conditions, investigators selected a CTC-medicated granular mineral product that is commonly fed in a free-choice manner on cow-calf operations in Mississippi and surrounding states.

In 1957, Brock et al. found that a 1.1 mg/kg/day dose of CTC was sufficient to prevent clinical anaplasmosis in cattle challenged with *A. marginale*. This study also demonstrated this dose to be effective at preventing challenged animals from becoming persistently infected carriers of *A. marginale* when hand-fed daily.[16] Currently, the label-indicated dose of CTC for control of active anaplasmosis in cattle is 1.1 mg/kg/day for products labeled to be hand-fed, while the target dose for products labeled to be fed free-choice is 1.1 to 4.4 mg/kg/day.[17-19] In the present study, few cattle consumed an average daily dose of 1.1 mg/kg/day or greater. Additional studies are needed to determine if doses lower than 1.1mg/kg/day would be sufficient to prevent disease due to BA.

To the author's knowledge, this is the first study to observe the effect of cow age on amount and frequency of mineral supplement consumption. In a 2004 study, Arthington and Swenson found reproductive performance in cows > 4 years of age was not affected by method of mineral delivery (i.e., hand fed or free-choice).[20] In this same study, they also found that cows, regardless of age, that were fed mineral supplement free-choice consumed less mineral on average compared to those cows that were hand fed mineral. In 2021, McCarthy et al. used feeding units similar to those used in the present study to measure intake of mineral offered free choice to beef cows and calves on native range pasture in North Dakota. In this study, they found the mean mineral intake of both cows and calves for the duration of the trial period did not meet the mineral manufacturers' feeding recommendation for daily mineral consumption, because neither cows nor calves visited the mineral feeder each day, but both cows and calves exceeded manufacturers' recommended daily consumption on days when they did visit the feeder.[12] Because beef cattle require small quantities of trace minerals, and mineral consumption does not need to be consistent to maintain physiologic function, the effect of older cows consuming less total CTC-medicated mineral in the present study and having a decreased frequency of days when CTC-medicated mineral was consumed, is unknown.[21-23] Additionally, the present study observed differences by pasture group in number of days when any amount of DDG/NaCl diet was consumed, the total amount of DDG/NaCl diet consumed, the total days when any amount of CTC-medicated mineral was consumed, and total days during the 46-day trial period when at least the label-indicated dose (1.1 mg CTC per kg body weight) of CTC was consumed. Although all pastures were managed similarly, and forage composition of pastures was similar, the investigators speculate that inherent differences in forage mineral content may explain the differences observed by pasture during both the adaptation and the trial periods.

Inconsistent intake of free-choice mineral supplements used as a vehicle to deliver medications to cattle on pasture presents a challenge to medication delivery. Previously, clearance of the *A. marginale* persistent carrier state was achieved in Holstein steers experimentally infected with the Virginia isolate of *A. marginale* and hand-fed CTC at either 4.4 mg/kg/day, 11 mg/kg/day, or 22 mg/kg/day. These doses are extra-label however, and therefore prohibited under the current VFD regulations.[24] Curtis et al. (2021) reported that when the labeled dose of CTC (1.1 mg/kg/day) was fed for 60 days, clearance of the persistently infected carrier state was not achieved.[25] The authors speculate that if CTC-medicated mineral is provided for long periods of time, a practice that is common in the southeast and other parts of the U.S. where *A. marginale* infection is endemic, it is possible for some cattle to inadvertently achieve clearance of the *A. marginale* persistently infected carrier state by consuming doses of CTC that exceed 1.1 mg/kg/day for extended periods of time. Additionally, the authors speculate that prolonged exposure to sub-therapeutic doses of CTC may also contribute to the development of antimicrobial resistance in circulating strains of *A. marginale*.

It is known that cattle conserve and store microminerals in various tissues throughout the body, and do not necessarily need to consume these nutrients daily.[1,23] It is also known that cows will over-consume based on the animal's appetite for salt (i.e., NaCl), not their physiologic need.[1,23] In the present study, the authors speculate that CTC-medicated mineral intake may have been influenced by other factors not measured such as individual animal appetite for NaCl, competition for feeding space, stocking density, and individual animal physiologic mineral status. Differences in the palatability of CTC-medicated mineral offered during the trial period compared to the DDG:NaCl mixture fed during the adaptation period may explain the differences in feeding behavior observed when the adaptation diet was replaced by the CTC-medicated mineral. Although the animals used in this study had previously been exposed to the SmartFeed units, it must be considered that the units themselves may have influenced the cattle feeding behavior observed in this study. It is possible that the free-choice mineral supplement consumption patterns of the cattle used in this study may differ if a more traditional feeder design was utilized to deliver free-choice mineral supplement. Further research is warranted to explore the relationship between these factors and patterns of daily mineral consumption, as well as their implications on health outcomes, production outcomes, and using mineral supplements as a vehicle for delivery of CTC to cattle on pasture.

Endnotes

[a] Microsoft Excel, Microsoft Corporation, Redmond, WA

[b] High-Performance ISO Half Duplex Electronic ID Tag, Allflex USA

[c] SmartFeed; C-Lock Inc., Rapid City, SD

[d] Purina® Wind & Rain® Storm® All Season 4 Complete AU5600 Medicated, Purina Animal Nutrition LLC, Arden Hills, MN

[e] SAS for Windows v9.4, Cary, NC

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