Impact of increasing levels of NaSO₄ in drinking water on the intake and utilization of low-quality forages by beef cattle hand-fed a protein supplement containing 25% salt

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INTRODUCTION

Livestock production systems across the United States and Canada rely on natural reservoirs, springs, and rivers/streams to provide water for livestock. Water quality can be influenced by geology, subsurface basin depth, recharge site soil chemistry, and precipitation (Anderson and Woosley, 2005; Petersen et al., 2015). Thus, the inorganic qualities (e.g., sulfates) of drinking water on rangelands used for livestock grazing in the United States and Canada have been reported to be highly variable (Gould et al., 2002; Anderson and Woosley, 2005; Penner et al., 2020). Furthermore, sulfate content of surface water greater than the recommendation for livestock consumption (>1,000 mg/L) are common throughout rangelands in the western and north-central regions of the United States and central Canada (Gould et al., 2002; Penner et al., 2020). However, it has been reported that sulfate concentrations generally considered safe for consumption (583–1,000 mg/L) can still lead to decreased growth and performance of feedlot cattle (Loneragan et al., 2001).

In order to meet the nutritional needs and maintain a desired level of productivity during times of seasonal deficiencies, supplemental protein is often provided to increase intake of forages and, as a result, performance (Lusby et al., 1967; Bowman and Sowell, 1997; Bodine et al., 2001). Under most rangeland cattle production scenarios, self-fed systems are often preferred due to ease of delivery and reduction in labor. The most common method to limit over consumption of self-fed supplements is by including 20%–30% salt (NaCl) to the supplement composition (Weir and Torell, 1953; Rush and Totusek, 1975; Kunkle et al., 2000).

Although it has been proposed that water quality can have an impact on intake of self-fed, salt limited supplements and cattle performance (Petersen et al., 2015), research is limited. Therefore, the objectives of this research were to evaluate the effects of varying sulfate concentrations of water on forage and water intake, digestibility, digestive kinetics, and ruminal fermentation characteristics of cattle consuming low-quality forages provided protein supplement (with and without salt). We hypothesized that the concentration of sulfates in the water and protein supplement composition can have a direct effect on intake and ruminal digestion of cattle consuming low-quality forage.

MATERIALS AND METHODS

All protocols and procedures for this research was approved by the Agricultural Animal Care
and Use Committee of Montana State University (2020-AA04).

Eight, ruminally cannulated cows (2-yr age) were used in two concurrent 4 × 4 Latin square study designs (four cows per study) to test the effects of increasing NaSO₄ water concentrations on forage and water intake, digestibility, digestive kinetics, and ruminal fermentation characteristics of cattle consuming low-quality forages provided protein supplement (with and without salt). Within each study, cows were randomly assigned to one of four NaSO₄ water concentration treatments: 1) control; 2) 700 mg/L; 3) 1,400 mg/L; and 4) 2,100 mg/L. Each cow was penned individually, with each pen having an individual feed bunk and a water trough mounted to a digital scale for measuring individual animal dry matter and water intake. All cattle were fed low-quality chopped grass hay (>65% NDF and <8% CP) at 0800 daily provided at 120% of the previous 3-d average as-fed intake. Water, respective to each NaSO₄ treatment, was offered ad libitum. All cattle were provided a crude protein supplement to meet the maintenance requirements of mature, non-lactating, beef cows, however, protein supplement NaCl composition differed by study (no NaCl vs. 25% NaCl). In study 1, cattle were hand-fed a canola-based supplement containing no NaCl at 0.18% of body weight daily (0800). In study 2, cattle were provided the same supplement with the addition of 25% NaCl that was mixed thoroughly and hand-fed at 0.24% of body weight daily (0800).

Each study included four 24-d periods, where cows were adapted to their respective water NaSO₄ treatment for 14-d prior to initiating intake and digestion data collection. During the following 7-d sample collection period (d 15–21); feed, orts, water disappearance, and fecal output were measured for each individual animal. Feed and orts samples were dried at 55 °C for 48-h to determine dry matter intake and fecal samples were dried at 55 °C for 96-h in a forced air oven and ground to pass through a 1 mm screen using a Wiley mill. On d 22, ruminal fluid samples were obtained using a suction strainer just prior to feeding (0-h) and at 4, 8, 12, 18, 24 h post-feeding to determine ruminal fermentation characteristics (Raun and Burroughs, 1962). Ruminal fluid samples were measured for pH immediately after extraction, then samples were stored at −20 ° C. Ruminal fluid samples were analyzed for ammonia (NH₃) concentrations using methods described by Sigma Technical Bulletin #640. Individual volatile fatty acid (VFA) concentrations were analyzed using a gas chromatography procedure. On d 23, ruminal contents were manually evacuated 5 h post feeding via the ruminal cannula. Total contents were weighed, thoroughly mixed and subsampled in duplicate (Van Soest, 1994). Ruminal subsamples were then dried in a forced-air oven at 55 °C for 96-h to determine liquid and dry matter fill. Dried ruminal sample were then composited and ground to pass through a 1-mm screen in a Wiley Mill. Feed, orts, and fecal samples were then analyzed for neutral detergent fiber (NDF; Ankom 200 Fiber Analyzer, Ankom Co., Fairport, NY) for estimation of total tract dry matter and NDF digestibility.

The effects of NaSO₄ level on dry matter and water intake, digestibility and fermentation characteristics were analyzed using an ANOVA with a generalized linear model for a 4 × 4 Latin square design. Volatile fatty acids, pH, and ammonia were analyzed using an ANOVA with a generalized linear model for a Latin square design with repeated measures. Data were log-transformed to meet the assumptions of normality and homogeneity of variance. An alpha ≤0.05 was considered significant and tendencies were considered between 0.05 and 0.10. Orthogonal polynomial contrasts were used to determine linear and quadratic effects for each analysis and means were separated using the Tukey method when P < 0.05. All statistical analyses were performed in R (R Core Team 2020).

RESULTS

Study 1: Hand-Fed Protein Supplement, No Salt

There were no observed effects (P ≥ 0.27) of NaSO₄ levels of drinking water on forage intake when expressed as either kg/d or g/kg body weight, averaging 12.43 kg, and 24.02 g/kg daily (Table 1). Additionally, water intake, expressed as either L/d or mL/kg body weight, did not differ (P ≥ 0.27) across NaSO₄ water concentrations (48.24 L, 94.35 mL/kg). Ruminal dry matter and liquid fill were also not influenced (P ≥ 0.68) by NaSO₄ water concentrations. Likewise, dry matter and NDF digestibility were not affected (P ≥ 0.49) by NaSO₄ levels of drinking water, averaging 57.24% and 57.95 %, respectively. There was no treatment × time interaction (P ≥ 0.73) observed for ruminal fermentation characteristics; therefore, data is presented by NaSO₄ treatment levels averaged across time (Table 1). Water NaSO₄ concentrations had no effect (P ≥ 0.40) on ruminal pH, ammonia, or total volatile fatty acid concentrations. Individual volatile fatty acid concentrations and the acetate to propionate ratio were also not influenced (P ≥ 0.12) by NaSO₄ water concentrations.
Study 2: Hand-Fed Protein Supplement with 25% Salt

Similar to study 1, there were no observed effects ($P \geq 0.47$) of NaSO$_4$ levels of drinking water on forage intake when expressed as either kg/d or g/kg body weight, averaging 12.05 kg, and 23.65 g/kg daily (Table 2). Water intake, expressed as L/d and mL/kg body weight, also did not differ ($P = 0.11$) across NaSO$_4$ water concentrations (53.28 L, 103.26 mL/kg). Ruminal dry matter fill (kg/d and g/kg body weight) tended ($P \leq 0.07$) to linearly decrease ($P \leq 0.05$) with increasing NaSO$_4$ water concentrations. However, there was no effect ($P \geq 0.85$) of NaSO$_4$ levels of drinking water on liquid fill (kg and g/kg bodyweight). Neither dry matter nor NDF digestibility were influenced ($P \geq 0.53$) by NaSO$_4$ levels of drinking water, averaging 56.33 and 56.47 %, respectively. There was no treatment × time interaction observed ($P \geq 0.37$) for ruminal fermentation characteristics; therefore, data is presented by NaSO$_4$ treatment levels averaged across time (Table 2). There were no effects ($P \geq 0.39$) of treatment water NaSO$_4$ concentrations on ruminal pH, ammonia, or total volatile fatty acid concentration. Additionally, there were no water NaSO$_4$ level effects ($P \geq 0.78$) on acetate, propionate, acetate to propionate ratio or butyrate. There was a tendency ($P = 0.08$) for an effect of NaSO$_4$ water level on ruminal isobutyrate concentration, however, there were no effects ($P \geq 0.19$) of NaSO$_4$ water level observed when making treatment comparisons. Ruminal isovalerate concentrations were influenced ($P = 0.03$) by the level of NaSO$_4$ in drinking water where ruminal isovalerate decreased with increasing NaSO$_4$ treatment levels ($P < 0.01$).

**DISCUSSION**

Our results are similar to previous research that suggest forage intake and digestibility are relatively unaffected by water NaSO$_4$ under 2,100 mg/L (Harper et al., 1997). However, when including a supplement with 25% salt as an intake limiter, levels of NaSO$_4$ in drinking water may alter ruminal fill and fermentation. Past research has reported an average 10 L increase in water consumption in response to feed/supplements containing 25% salt (Croom Jr. et al., 1982; White et al., 2019). Although we observed an increase in water intake with the addition of 25% salt in the supplement, the magnitude was less than previous reported (2.5 L). Therefore, our results suggest that the maximum NaSO$_4$ concentration in livestock drinking water
could be raised to 2,100 mg/L, however, the interaction of salt containing supplements and water quality warrant additional investigation.

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### Table 2. Effect of increasing water NaSO₄ levels on intake, digestibility, ruminal fill and ruminal fermentation characteristics of 2-yr-old cows consuming low-quality forages and hand-fed a protein supplement containing 25% salt (Study 2)

| NaSO₄ water concentration (mg/L) | P-values |
|---------------------------------|---------|
|                                  | SEM     |
|                                  | TRTᵃ    | LINᵇ    | QUADᶜ   |
| 0                               | 0.50    | 0.71    | 0.84    | 0.64    |
| 700                             | 0.92    | 0.47    | 0.69    | 0.71    |
| 1,400                           | 1.16    | 0.11    | 0.15    | 0.43    |
| 2,100                           | 2.44    | 0.11    | 0.14    | 0.96    |

Forage intake, kg
- Forage intake, g/kg body weight
- Water intake, L
- Water intake, mL/kg body weight
- Dry matter fill, kg
- Dry matter fill, g/kg body weight
- Liquid fill, kg
- Liquid fill, g/kg body weight
- Dry matter digestibility, %
- NDF digestibility, %
- pH
- Ammonia, mg/dL
- Total VFA, MM
- Acetate:propionate ratio
- Acetate, mol/100 mol
- Propionate, mol/100 mol
- Isobutyrate, mol/100 mol
- Butyrate, mol/100 mol
- Isovalerate, mol/100 mol

ᵃTreatment main effect.
ᵇLinear preplanned contrast.
ᶜQuadratic preplanned contrast.

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