THE INFLUENCE OF OFFERING A SALT-LIMITED PROTEIN SUPPLEMENT WITH OR WITHOUT A SALT-LIMITED MINERAL TO BEEF CATTLE GRAZING SUMMER/FALL DRYLAND PASTURES

by

Jacqueline Lee Pondolfino

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ABSTRACT

Beef cattle producers on rangelands often utilize supplements to meet protein and mineral nutrient requirements of beef cattle when the forage resource is high in fiber and low in crude protein and mineral nutrition. These supplements are often offered free choice, relying on sodium chloride as an intake modulator. However, it is unknown how offering multiple salt-containing supplements influences intake of one another. A supplement intake study was performed to observe the effects of offering multiple salt-containing supplements on intake behavior of each supplement and subsequent animal performance of yearling heifers at the Fort Ellis Research and Teaching Farm in Bozeman, Montana. Three treatments were offered in a complete randomized design utilizing a SmartFeed Pro feeding station during the summer-fall grazing period over two consecutive years: 1) ad libitum 25% NaCl protein pellet only; 2) ad libitum 25% NaCl loose mineral; and 3) ad libitum access to both salt-containing supplements. Heifer supplement intake displayed a treatment × period × year interaction ($P < 0.01$). Mineral-only heifers generally exhibited greater mineral intake (kg/day; g/kg BW; $P < 0.01$) compared to heifers consuming both salt-limited supplements in periods 2 and 3 of year 1 and all three periods of year 2. Meanwhile, there were generally no treatment differences in protein supplement intake between protein-only heifers and heifers consuming both salt-containing supplements ($P \geq 0.71$). The temporal decline in forage crude protein and increase in forage fiber content in year 1 likely contributed to differences in voluntary protein intake across periods. Meanwhile, differences in voluntary protein intake between years 1 and 2 of the study may be explained by environmental characteristics, with voluntary protein intake increasing quadratically throughout year 1 as forage crude protein and fiber remained stable across periods in year 2 when forage quality did not decrease. In conclusion, our results indicate that the providing multiple salt-containing supplements (protein and mineral) may reduce intake of loose mineral salt and that voluntary protein supplement intake and variation may be influenced more by environmental / temporal conditions.

GENERAL INTRODUCTION

Beef Cattle Production in the Western United States

Rangelands cover approximately half of the global land area and provide habitat for both wild and domesticated ruminant species (Van Soest, 1994). Grazing use by domesticated species, including *Bos taurus* (cattle) and *Ovis aries* (sheep), are integral to agricultural economies, particularly in areas where rangelands dominate the landscape, such as the Western United States (DelCurto et al., 2023). Ruminants possess a unique ability to utilize fibrous, low-quality forages, making them highly efficient livestock for agricultural systems of the regions characterized by rangelands (Moore et al., 1999; Van Soest, 1994). Rangelands account for approximately 31% of land area in the United States, equating 308 million hectares in the Western United States (Havstad et al., 2009). In addition, beef cattle receipts are forecasted to be $129.8 billion in the United States in 2025, (Knight and Brooks, 2025; Nelson and Parum 2025) with indirect contributions that fuel local economies (Tanaka et al., 2007).

Despite their evolutionary advantage to utilize rangeland forages, ruminants face nutritional limitations due to decreased crude protein and digestibility of mature, cool-season grasses, which form the forage base for many grazing systems of the northern Great Plains. Short growing seasons, limited and variable precipitation patterns, and forage senescence often result in lower protein, higher fiber, and decreased digestibility of the available forage (DelCurto et al., 2023; Hibbard et al., 2021). As beef cattle producers strive to meet a growing domestic and international demand for beef, the variability in rangeland forages present seasonal nutrient limitations to grazing livestock. This necessitates that producers stockpile forages, rely on harvested feeds, or utilize nutritional supplements to meet the dietary needs of their herds,

particularly during periods of increased physiological demands (DelCurto et al., 2000; DelCurto et al, 2023).

Profitability of cow-calf operations hinges on managing input costs while maintaining the health and productivity of developing and mature breeding females. Improvements in heifer development strategies are critical for maintaining longevity of cow/calf herds and nutritional management contributes to timely reproductive maturity so heifers may calve as two-year olds in the existing production cycle (Patterson et al., 1992). However, the feed costs associated with meeting a heifer's physiological demands for growth, breeding, gestation, and lactation are significant (Mulliniks et al., 2013; Wyffels et al., 2019). The nutritional inputs necessary to meet physiological demands – including hay, protein, and mineral supplements - can account for 35-40% of variable production costs across the Great Plains (Economic Research Service, 1995; Adams et al, 1996). Given that supplemental feeding represents a substantial portion of production costs, strategies to improve the efficiency of supplement formulations, delivery mechanisms, and that promote uniform animal intake are critical to maintaining profitability for these forage-based operations (DelCurto et al., 2000; Kunkle et al., 2000; Bowman and Sowell, 1997). Therefore, even slight improvements to supplementation regimes stand to improve the economic efficiency of forage-based production systems.

Sodium chloride, a key intake modulator, improves the palatability of mineral supplements while limiting the intake of protein supplements to prevent overconsumption and waste. Subsequently, salt is widely utilized in supplements designed to be offered to grazing beef cattle. Water quality studies indicate that salts in stock water may reduce intake of mineral salt, leading to concerns of how compounding levels of salt form environmental and dietary sources

may influence supplement intake behavior of salt-limited supplements (Petersen et al., 2015; Embry et al., 1959). Despite wide use of salt-limited supplements, there remains a gap in the research concerning the practice of offering multiple salt-limited supplements, and how compounding amounts of salt interact and influence intake of salt-limited supplements.

CHAPTER TWO

LITERATURE REVIEW: SALT AS AN INTAKE MODULATOR AND ITS EFFECT ON SUPPLEMENT INTAKE BEHAVIOR

The Need for Supplementation

Ranchers are facing increasing pressure to maximize production on existing forage resources (Meyer & Gunn, 2015; Tonsor and Schultz, 2015; DelCurto et al., 2000). Forage based diets, while essential for ruminant livestock, often fail to provide adequate protein, energy, and minerals due to the relatively low nutrient content of mature and dormant rangeland forages (Adams et al., 1996). Additionally, individual animals within a herd have different nutrient requirements and varying tendencies to select from the available forage resources (Kunkle et al., 2000). To address these challenges, many producers utilize protein and mineral supplements to ensure the herd's nutritional needs are met during periods of increased production demands and/or low forage nutrient density.

The nutrient requirements of ruminant species are influenced by factors such as age, body size, environmental conditions, production expectations, and genetics (Kunkle et al., 2000). The *Nutrient Requirements of Beef Cattle* (NRC, 2016) contains current recommendations for nutrition management of beef cattle at various stages of production. While grazing ruminants depend on forage for the bulk of their nutrient requirements, available forage is subject to seasonal variability, most notably crude protein and minerals (Kunkle et al., 2000; Gaylean, 2015).

The crude protein content of forages varies among species, climate, plant part, and maturity (Gaylean, 2015). Short growing seasons, elevation, and low seasonal precipitation result in rangeland forages that do not meet animal nutritional requirements consistently (Krysl and Hess, 1993). Additionally, the nutrient content of forages varies within land resource areas, depending on factors such as soil, climate, and topography (DelCurto et al., 2000). For example, cool season plants that are actively growing may exceed 10% crude protein, however, later in the season, mature/dormant cool-season plants may have only 4-7% crude protein (Adams and Short, 1988). Considering that rumen microbial populations require at least 7% crude protein in the diet, grazing on low-quality forages can limit animal performance (Van Soest 1994). Furthermore, physical limitations on forage intake arise due to rumen capacity and slower digesta passage in nitrogen-deficient forages (McCollum and Horn, 1990). When the available forage resource is high in fiber and low in protein, beef cattle are limited by rumen capacity, necessitating the use of protein and mineral supplements to maintain condition and performance.

Over centuries, ranchers have developed various strategies to mitigate seasonal deficiencies in forage crude protein, including pasture rotations, which expose herds to cooler microclimates at higher elevation or forested pasture during the growing season while pastures at lower elevations are used from late fall to early spring (Gaylean, 2015). Harvested feeds such as alfalfa, grass, barley hay are often provided in winter when snow limits access to forage. Finally, when forage quantity is not limited, protein supplements made from cottonseed, linseed, alfalfa, or other byproduct meal are used to meet the protein requirements of cattle grazing low-quality forage on rangelands or dryland pastures.

When the available forage resource is high in fiber but low in protein and digestibility, the use of protein supplementation becomes highly beneficial. Protein supplementation improves voluntary forage intake and increases the digestibility of low-quality forage, which in turn enhances the efficiency with which cattle use the available forage (McCollum and Horn, 1990; DelCurto et al., 2000). Studies have shown that protein supplementation is especially important in nitrogen-deficient diets, as it supports improved forage utilization (DelCurto et al., 2000). Concerns with protein supplementation arise, however, due to cost and the incidence of over-consumption, resulting in inefficient utilization of a costly input. Therefore, intake limiters such as salt are added to protein supplements to limit consumption.

In addition to protein, supplementation of macro- and micro- minerals is also essential for grazing cattle, as mineral content can fluctuate with seasonal changes (Greene, 2016; Grings et al., 1996). The nutrients calcium, phosphorus, magnesium, sodium, chlorine, zinc, copper, iodine, manganese, and cobalt are often limited in forage-based diets, with their concentrations mirroring the decline in forage digestibility as plants reach maturity (Minson, 1990; Greene 2016). Inadequate mineral nutrition can lead to losses in production, reproduction, and decreased immunity (Greene, 2016). As nutrient content decreases, ruminants experience physical limitations to consumption of fibrous forages due to low digestibility and slow digesta passage (Allison, 1985; Van Soest 1994).

In most cases, mineral supplements are provided as blocks, tub formulations, or loose meals to give livestock free choice access to a mineral package that may be deficient in their forage (McDowell, 1993; Greene, 2000). However, a major challenge with self-fed mineral supplementation is the variability in individual animal intake. Forages often fail to provide

enough NaCl to meet animal requirements and cattle will seek it out when offered free-choice (Greene, 2000). Thus, salt often forms the base of mineral formulations. Salt can be used to improve the palatability of mineral supplements, often bitter in nature, relying on the craving for salt to encourage intake at target rates as prescribed by manufacturers to enhance performance and animal health benefits (Morris et al., 1980; Greene, 2000; Manzano et al., 2012). At the same time, higher inclusion rates of salt may also be used to limit overconsumption (Brokman et al., 2008).

Delivery Systems

Supplement delivery systems are generally categorized into self-fed and hand-fed methods. Hand fed systems provide specified amounts of supplement to individual animals or groups, ranging from daily to once weekly feedings, with less frequent feedings showing similar animal performance benefits (McIlvain and Shoop, 1962; Pope et al., 1962; Wallace, 1988; Coleman and Wyatt, 1982; Kunkle et al., 2000) and presenting fewer interruptions to grazing patterns (Huston et al., 1999). Hand-feeding supplements to groups tends to show decreased intake variation, however lower intake amount compared to individually-fed animals (Bowman and Sowell, 1997; Kincheloe et al., 2004). While hand fed systems allow producers more management of supplement intake, they are less practical in large, remote pastures where labor costs are prohibitive (Beaty et al., 1994).

Self-fed systems arose out of necessity due to labor shortages during World War II (Riggs et al., 1953) and their use remains popular due to the high cost of labor and inefficiency of hand feeding in extensive grazing scenarios. Self-fed systems follow the concept of “nutritional wisdom,” where animals are believed to recognize nutrient deficiencies and consume

supplements accordingly (Rod and Beauchemin, 1993), however, SF systems result in greater proportions of non-feeders and increased variation both between individuals and within individual over time compared to hand-fed(Bowman and Sowell, 1997). Previous research documenting average group supplement intake has led to misconceptions that self-fed systems allow slow-eating cattle or individuals lower in herd social hierarchy time to consume target rates. However, when individual animal intake is accounted for, the data reflect high intake variation and presence of non-feeders (Kunkle et al., 2000). Studies (Williams et al., 2018; Wyffels et al., 2021; Parsons et al., 2021; and Whtie et al., 2024) observe significant variability in protein supplement intake among individuals in self-fed systems. Furthermore, studies measuring mineral intake from electronic feeders also report high variability (Cockwill et al., 2000; Manzano et al., 2012; Patterson et al., 2013; McCarthy et al., 2021). Therefore, supplement formulations often include an intake limiter to prevent over consumption and waste of highly palatable supplements or control intake of mineral formulations.

Salt as an Intake Modulator

Sodium chloride is essential in the diet for all animals, maintaining osmotic pressure in the rumen, regulating acid-base balance, and controlling water metabolism (Petersen et al., 2015; Van Soest, 1994). Sodium plays an important role in physiological processes including muscle contraction, nerve signaling, and sodium-potassium pumps necessary for absorption of amino acid and monosaccharides (Grim, 1980). Chloride is necessary for maintaining acid-base balance in blood and production of hydrochloric acid (Barger and Cunha, 1993). NaCl is absorbed rapidly through the rumen lining into the bloodstream, where it is then excreted via the kidneys (Cardon et al., 1951). Ruminant animals are also able to conserve sodium in the gastrointestinal

tract, enabling them to draw from stores when sodium requirements are not met (Underwood and Suttle, 1999). Bell (1984) proposed that the appetite for salt has multiple control mechanisms, including chemo-receptors of the alimentary tract (salivary flow regulation) and hormonal mechanisms that metabolize sodium (kidney excretion).

Cattle can tolerate relatively large amounts of NaCl without adverse symptoms, provided that fresh drinking water is available. The ability of cattle to tolerate high NaCl levels has made it a preferred intake modulator in supplement formulations, especially when used in combination with other methods such as supplement form. The first reported use of salt as an intake limiter dates to the 1930s, when Texas cattlemen mixed 25% salt with cottonseed meal to limit consumption of supplement by cattle grazing low-quality forages (Cardon et al., 1951). In 1946, the *Grazier's Annual of Australia* reported that "the use of salt fodders . . .greatly reduce labor." The article added that scientific evidence supporting the practice was lacking and provided an example formulation of 40% linseed meal, 40% crushed grain, and 20% salt. In response, research by Cardon et al. (1951) provided evidence to support that cattle could tolerate large amounts of salt, up to .91 kg per day, without abnormal symptoms (Cardon et al., 1951;). Since then, the practice has been widely adopted, with increasing evidence supporting its effectiveness at limiting supplement intake. At concentrations of 13-17%, sodium chloride has been shown to effectively limit intake of concentrate supplements in extensive sheep production systems without negatively impacting reproductive performance (Sphor et al., 2021). Kunkle and colleagues (2000) recommended producers begin incorporating salt into supplements at a rate of .1% BW and adjust based on animal intake. Kunkle et al. (2000) also stated that cattle tend to increase intake of salt over time.

Research on the influence of NaCl on forage digestibility is inconsistent. Results from research by Archer (1952), Cardon (1951), and Nelson et al. (1955) report no influence of NaCl on rumen digestion. In contrast, Riggs et al. (1953), Brandyberry et al. (1991) documented improvements in digestibility in cattle consuming salt-limited protein supplements. Recently, White et al. (2024) reported that forage intake, expressed as g/kg BW, decreased with greater levels of dietary salt. Findings also reported that increasing dietary salt was associated with lower ruminal pH and ammonia levels, which can be detrimental to cellulolytic bacteria (White et al., 2024; Van Soest, 1994). In summary, this recent research indicates that high levels of NaCl – often available from drinking water, nutrient supplements, and/or forages – may alter ruminal fermentation and digesta kinetics, leading to decreases in efficiency.

Salt, despite its effectiveness at limiting intake of highly palatable supplements and inclusion in mineral supplements, requires further research to understand the implications of its use on supplement intake, cattle health, productivity, and feed efficiency. Despite its popularity as an intake modulator, much remains unknown about how compounding levels of salt in the diet, from stock water, forages, and nutrient supplements impacts grazing, water consumption, and supplement intake.

Salt in the Environment

Sodium is available in stock water, forage, and concentrate feeds at varying amounts. Petersen et al. (2015) found nearly half of sampled stock water locations at Fort Keough USDA experiment station to have sodium levels exceeding the maximum upper level of 300mg/L (Socha et al., 2003). Petersen et al. (2015) provided rationale that cattle will express preference for salty water if the diet is deficient in sodium. In contrast, cattle will refuse salty water if

sodium is sufficient in the diet. This is operating under the assumption that cattle will adjust sodium intake to maintain homeostasis (Carlson and Bruss, 2008; Petersen et al., 2015). Babcock's observations support this theory, reporting an 'abnormal appetite' for NaCl in sodium-deprived cows (1905). Results from a trial by Embry and others (1959) showed that steers drinking high NaCl stock water had depressed mineral intakes compared to a control group. Additionally, consuming salt-limited supplements have shown to correspond with animals drinking more stock water (Nack et al., 2021; White et al., 2019). When we consider added salt in supplement formulations, how does NaCl in turn influence water consumption, forage intake, and intake of other supplements?

Supplement Intake

A successful supplementation program aims to ensure that livestock consume target supplement amounts on an individual animal basis and overtime (Bowman and Sowel, 1997). Supplement intake is often measured as supplement disappearance divided by number of animals and number of days. Due to the resource-intensive nature of intake studies, researchers have often relied upon replications utilizing groups of 4-8 animals as an experimental unit (DelCurto and Wyffels, 2024). However, this method of measuring intake provides a group average and often fails to account for individual animal intake and subsequent animal performance (DelCurto and Wyffels, 2024). This approach may overlook "non-feeders," animals whose nutrient needs are not being met, and "overfeeders," individuals that waste supplements, and consequently decrease their feed efficiency (Bowman and Sowell, 1997). Additionally, intake studies utilizing internal and external markers (e.g., chromium, ytterbium and tritiated water), followed by fecal collections and direct weighing, often required placing cattle in pens, leading to results that may

not capture the intricacies of animal behavior and performance in production scenarios (DelCurto and Wyffels, 2024; Cockwill et al., 2000). Finally, the use of internal and external markers is a resource-intensive process and involves significant margins of error due to non-homogonous mixing of marker into feed, lack of statistical power in study design, and multiple fecal collections per day. Recent technology has made it possible to track intake at the individual animal level with the use of feed-intake monitors equipped with electronic identification tag readers (DelCurto and Wyffels, 2024). Devices such as the SmartFeed Pro (C-lock Inc, Rapid City, SD) enable researchers to measure feed intake rates, intake events, and intake amounts on an individual animal basis. This technology allows for more accurate assessments of the factors influencing supplement intake behavior on an individual animal basis.

Supplement intake variability can be quantified using measures such as the coefficient of variation (CV, %) of individual animal intake, the percentage of non-feeders, and the proportion of animals consuming target supplement amounts (Bowman and Sowell, 1997). This variability is an essential measure in assessing the impact of supplementation on herd performance, including outcomes such as body weight (BW) gain, body condition score (BCS) improvements, and reproductive efficiency.

Factors Influencing Mineral Salt Intake Behavior

Self-fed mineral supplements are often mixed with salt to modulate intake, however studies measuring mineral salt intake in range settings display high intake variation (Cockwill et al., 2000; Arthington and Ranches, 2021). Most minerals, excluding Selenium, have a wide range of tolerable intake (NRC, 2016), meaning that toxicity due to over consumption is rare. Greene (2000) recommends free choice mineral be consumed within the range of 56 – 114 g/day.

Generally, the benefits of a mineral supplementation program outweigh waste associated with overconsumption (Cockwill et al., 2000). Therefore, the motivation for adding salt often relates to encouraging animal intake and the craving for salt largely drives mineral intake (Arthington and Ranches, 2021). Nevertheless, Results from a 2-week mineral intake study, using a GrowSafe self-feeder, found cow-calf pairs consumed more of a low salt (241.6 g/d; 9.8 % NaCl) than a high salt (183.5 g/day; 22.5 % NaCl), indicating that salt could also be utilized to limit overconsumption of mineral (Cockwill et al., 2000). Another study utilizing Holstein steers found that a 60% inclusion rate of salt lead to intakes below the target range proposed by Greene (2000), averaging 35 g/day in year one and 52 g/day in year two of a two-year mineral intake trial (Brokman et al., 2008). Therefore, there appears to be a limit to how much salt may be included in mineral supplement to allow for target intake. However, it remains unknown how multiple supplements that rely on salt to control intake interact in terms of animals meeting daily mineral supplement target intake.

Manzano and colleagues (2012) offered 25% salt trace mineral under ideal forage conditions (> 10 % CP) and found that steers had higher mineral intake (96 g/day) in the spring-early summer grazing period than the fall grazing period (86 g/day) but found no correlation between daily mineral intake and daily precipitation, maximum, or minimum temperature. Similarly, Dixon and colleagues (2001) observed a linear increase in mineral intake over the course of a 9-week monitoring period. This provides further evidence in favor of the theory that cattle adapt to dietary salt and may increase consumption of salt-containing supplements (Kunkle et al., 2000) or that seasonal availability from other environmental sources influences mineral intake (Arthington and Ranches, 2021). Cockwill and others (2000) stated that salt craving

increases when there is adequate precipitation and decreases during dry periods. Furthermore, coastal regions where sodium needs are adequate or excessive, due to the sodium available in forages and stock water, cattle may avoid salt-containing supplements (Arthington and Ranches, 2021).

Because free-choice consumption of trace mineral is driven by salt cravings, variation in mineral intake is anticipated (Arthington and Ranches, 2021). Manzano and colleagues (2012) reported a coefficient of variation for mineral intake of 77.5 – 108.4 %.

Factors Influencing Salt-limited Protein Intake Behavior

Despite the effectiveness of salt as an intake-modulator, there are other factors that contribute to variability in supplement intake, including supplement form, supplement hardness, palatability, social hierarchies within a herd, forage availability and quality, the supplement delivery system, feeding space, and distance of the supplement from resources such as water, shade, and forage (Bowman and Sowell, 1997, Wyffels et al., 2020). Furthermore, Adams noted that ambient temperature may affect feed intake patterns, with cattle in hotter environments consuming less feed (1988). Research in Northern Montana has shown the influence of cow age on supplement intake behavior (Wagnon et al., 1965; Sowell et al., 2003; Wyffels et al., 2020; Wyffels et al., 2021; Parsons et al., 2021). Wagnon (1965) indicated that increasing cow age was highly associated with higher social dominance in the cow herd. In general, higher social dominance is associated with higher supplement intake (Sowell et al., 2003; Wagnon et al., 1965). Results by Sowell et al. (2003) support this association, with the youngest age group (2-yr-old) of cows having the lowest supplement dry matter intake (DMI) and 4-6yr old cows having the highest supplement DMI at an experiment at USDA Fort Keough Livestock and

Range Farm (Wagnon et al., 1965). These findings suggest that age-related factors, such as experience and physical development, may play a role in intake behavior. However, recent studies at Northern Agricultural Research Center measuring individual animal intake utilizing a commercial mixed-age cow herd report add more to the discussion regarding the influence of cow age on supplement intake behavior (Wyffels et al., 2020; Wyffels et al., 2021; Parsons et al., 2021).

Parsons and colleagues (2021) measured a range of factors – including residual feed intake (RFI), BW, BCS, and supplement intake behavior – of commercial Angus cows of varying ages (1-10 years). Cows were provided with a 25% salt, canola-based protein pressed block supplement via the SmartFeed Pro system (C-Lock Inc, Rapid City, South Dakota). Results from revealed a quadratic effect of both RFI and cow age on supplement intake variation. Specifically, 1-year-old heifers exhibited the highest CV in supplement intake. Data showed that cows aged 2-4 years spent more time at the feeder compared to both younger and older cows, suggesting that age and experience may affect how cattle access and consume supplements.

Wyffels and coworkers (2021) examined the influence of age and environmental conditions on voluntary protein supplement intake over two consecutive winter grazing periods utilizing a SmartFeed Pro System. They observed a $temperature_{windchill}$ × cow age × year interaction, where cow age showed a quadratic effect on all supplement intake variables. In this study yearling cattle consumed the least supplement and exhibited the greatest variation in intake. Meanwhile, the 3- to 4- year old cows exhibited the greatest intake amount and lowest variation, indicating that age related factors, such as experience and physical development may play a role in intake behavior.

Wyffels et al. (2020) also evaluated supplement intake behavior of commercial herd of cows ranging in age from 1 – 12 years old during the winter grazing season in Northen Montana. Cows were provided ad libitum access to a 30% CP canola meal using 25% salt in a SmartFeed Pro system. Results displayed a negative linear effect between cow age and average daily temperatures. In practical terms, these results indicate that younger cows have higher propensity to eat nutritional supplements during cold weather events, while older cows will bed down in shelterbelts to wait out the storm.

When we compare the findings from Parsons et al., 2021; Wyffels et al., 2021; and Wyffels et al., 2020, differences in age-related intake patterns indicate there are factors beyond cow attributes affecting supplement intake behavior, underscoring the complexity of managing supplement intake in cattle. These age-related differences appeared to interact with the environment and supplement form. Ensuring uniform intake across the herd requires careful consideration of not only animal characteristics, but also environmental conditions, supplement form, and delivery systems.

Supplement Form

Supplement form can significantly impact intake. The commercial feed industry produces supplements in various forms, including blocks, tubs, pellets, liquids, cubes, and loose meals (Bowman and Sowell, 1997). Bell and Kitchell reported that cattle possess taste receptors for salt, sweet, sour, and bitter (1966). A threshold for sweet substances has not been observed (Bell, 1984). Most frequently, bittering agents or salts are used to limit intake of highly palatable supplements and increase the palatability of otherwise bitter supplements such as mineral supplements. Salt is effective in controlling supplement intake, often in combination with other

factors like hardness (Schauer et al., 2004). Research by Schauer et al. (2004) compared the effectiveness of hardness versus salt as intake limiters. They found that salt has a strong ability to regulate supplement intake while also enhancing the palatability of otherwise unpalatable supplements, such as mineral blocks.

Pelletizing supplements may reduce the effectiveness of intake modulating agents such as salt, as the process decreases surface area (White et al, 2022; Dove and Freer 1986; Kunkle et al., 2000). In contrast, grinding supplements may increase the effectiveness of intake-modulating agents by allowing the meal to coat the tongue and enhance the anti-palatability effects (Minson, 1990; Gaylean, 2015; White et al., 2022).

White and colleagues (2022) compared voluntary intake behavior of grazing Angus crossbred heifers consuming loose versus pelleted forms of a 25% salt-limited protein supplement. Results showed that intake of the pelleted formulation ranged from 24% to 32% greater than the loose formulation. The data also showed that intake rate (g/min) of the pelleted formulation was 1.8 to 2.5 faster than the intake rate of the loose meal formulation. These results support the theory that intake-limiting effects of salt are greatly reduced in pelleted formulations compared to loose meal formulations.

Results from White (2022) indicate that supplement form influences protein intake behavior. Therefore, in extensive grazing systems, where salt is the method for modulating intake, managers must consider how supplement form and surface area enhance or reduce the intake-limiting effect of salt. However, a significant question remains: When there is NaCl in multiple sources – either from multiple supplements and/or the environment, how does it influence intake?

Rational for Research

The supplementation of grazing cattle is an essential management strategy to address the seasonal nutrient deficiencies posed by rangeland forage resources. While the primary goal of supplementation is to ensure cattle meet their nutrient requirements, variability in supplement intake remains a significant challenge. This variation arises from factors such as supplement form, palatability, delivery method, environment, herd dynamics, and individual animal characteristics, all of which can impact the success of a supplementation program.

While salt has shown to be a particularly effective intake modulator - both driving the intake of mineral supplements and limiting overconsumption of palatable supplements – it remains unknown how multiple sources of salt influence intake of salt-limited supplements. Salt is ubiquitous in supplement formulations, and it is also available to cattle from multiple environmental sources. Future research must carefully investigate the consequences of its overabundance in cattle production systems.

Common practice in many ranching enterprises is to provide a mineral package mixed with salt, a salt block or loose salt, and/or a salt-limited protein supplement. Furthermore, environmental concerns such as stock water containing high total dissolved solids and salinization of soils in areas throughout the west add to the compounding sources of salt available to cattle. Historically we have relied on salt to regulate intake of mineral, but if animals are presented salt from other sources, it remains unknown what the influence will be on supplement intake. There remains a gap in research concerning self-fed, salt-limited supplementation strategies, specifically how multiple salt-limited supplements interact with and influence intake of one another.

Advances in technology, such as the ability to monitor individual animal intake, offer promising avenues for understanding and managing supplement consumption on a more precise level. Ultimately, effective supplementation requires an approach that considers both the nutritional needs of livestock and the economic constraints of the producer. By improving supplement intake consistency and reducing waste, cattle producers can enhance the productivity and profitability of their operations while maintaining the health of their herds.

CHAPTER THREE

SALT-LIMITED TRACE MINERAL AND PROTEIN SUPPLEMENT INTAKE BEHAVIOR AND PERFORMANCE OF YEARLING HEIFERS GRAZING DRYLAND PASTURES

Contribution of Authors and Co-Authors

Author: J.L. Pondolfino

Contributions: Main author and lead scientist responsible for data collection, data analysis and interpretation, and drafting of this thesis

Co-Author: N.G. Davis

Contributions: Critical in data collection and data analysis

Co-Author: T. DelCurto

Contributions: Critical in experimental design and revisions

Co-Author: H. Goosey

Contributions: Critical in revisions

Co-Author: S.A. Wyffels Critical in experimental design, data collection, data analysis and interpretation, and revisions for this thesis

Manuscript Information

J.L. Pondolfino, N.G. Davis, T. DelCurto, H. Goosey, and S.A. Wyffels

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Abstract

This study evaluated supplement intake behavior and subsequent animal performance of 14-month-old heifers in response to multiple salt containing supplements while grazing Summer/Fall pasture over 2 consecutive years (n=160). Cattle were stratified by bodyweight and body condition score, and within stratum, randomly assigned to one of three treatments in a randomized complete design: 1) Ad libitum access to only loose mineral salt (25% NaCl); 2) Ad libitum access only salt-limited crude protein (25% NaCl); 3) Ad libitum access to both salt-containing supplements. Daily intake, time spent at feeder, intake rate, intake per unit bodyweight, coefficient of variation were measured continuously over 84 days using a SmartFeed Pro Trailer. There was no treatment effect on animal BW gain ($P \geq 0.58$) or BCS change ($P \geq 0.81$). All metrics of protein and mineral intake displayed a three-way interaction between treatment, period, and year ($P < 0.01$). In general, the presence of a salt-limited protein supplement coincided with decreased mineral intake compared to animals only allowed mineral supplement ($P < 0.01$). However, the presence of a mineral supplement did not influence protein supplement intake by heifers receiving both salt-containing supplements ($P \geq 0.71$). Our results showed that once the craving for salt was met, heifers prioritized consuming the palatable protein supplement over the mineral supplement. These results reinforce that supplement manufacturers and producers should consider sources of salt available to cattle, especially when relying on sodium chloride to encourage free-choice intake of critical mineral nutrition.

Introduction

Crude protein and mineral supplements are often provided to maintain productivity and condition of beef cattle grazing forages that are high in fiber and deficient in crude protein (CP) and mineral nutrition (NRC, 2016; McDowell, 1996; DelCurto et al., 2023). Supplemental CP improves the digestibility and intake of low-quality forages whereas mineral supplement supports hoof health as well as immune and reproductive function (McDowell, 1996; Greene, 2016; DelCurto et al., 2000). In extensive grazing scenarios, self-fed protein and mineral supplements are utilized to supplement livestock as they require less labor than hand-fed supplements. Salt, a key intake modulator, improves the palatability of mineral supplements while limiting excessive intake of highly palatable protein supplements. Although salt is generally considered safe even at high inclusion levels, recent studies suggest that excessive salt in the ruminant diet can impair digestive efficiency and overall cattle performance (Thompson, 2018; White et al., 2024).

Sodium chloride may be available to cattle in stock water, forage, and nutritional supplements at varying amounts. Petersen et al. (2015) observed that cattle express preference for salty water if the diet is deficient in sodium and refuse salty water when sodium is sufficient in the diet. This operates under the assumption that cattle will adjust sodium intake to maintain homeostasis (Carlson and Bruss, 2008; Petersen et al., 2015). In most cases, mineral supplements are provided as blocks, tub formulations, or loose meals, often utilizing salt as the base and relying on the craving for salt to drive intake (McDowell, 1993; Greene, 1999).

Despite its long history of use in beef cattle production systems, limited research has specifically addressed how cumulative salt levels from multiple dietary sources influence

supplement intake behavior by cattle. The objective of this research was to evaluate the interaction between salt-limited protein and mineral supplements on supplement intake behavior and subsequent animal performance. We hypothesized that offering multiple salt-limited supplements would influence supplement intake and intake behavior.

Materials and Methods

Experimental procedures described were approved by the Agriculture Animal Care and Use Committees of Montana State University (2022-AA09). Animals used in this study were provided by the Montana Agricultural Experiment Station.

This research took place at Fort Ellis Research and Teaching Farm of Montana State University in Bozeman, Montana (45°39′36.5″ N, 110°58′10.9″ W). The forage base primarily consisted of improved pasture grasses, including *Bromus inermus, Agropyron cristatum,* and *Poa pretensis.* The site elevation was approximately 1500 m. The 30-year normal annual precipitation at the site is 523 mm (PRISM). Both study years received greater-than-average precipitation, at 617 mm and 569 mm in years 1 and 2, respectively.

This study utilized 73 commercial crossbred heifers (year 1) and 87 heifers (year 2; n=160) which grazed improved pasture from mid-July through late October over two consecutive years (n=2). Animals were fitted with electronic identification [EID] tags attached to the left ear (Allflex USA, Inc., Dallas-Ft. Worth, TX, USA) and managed as a single herd (14 months of age; 384.48 kg ± 7.57 kg body weight [BW]; 5.4 BCS ± 0.06 body condition score [BCS]). Heifers were weighed and body condition scored by two trained technicians at the initiation of the study. Heifers were stratified by BW and BCS, and within stratum, randomly assigned to one of three supplement treatments. Supplement treatments consisted of 1) ad libitum access to a

25% NaCl protein pellet (30% CP, n=54), 2) ad libitum access to a 25% NaCl loose mineral (n=52), and 3) ad libitum access to both salt-modulated supplements (n=54).

Supplements were offered in a SmartFeed Pro trailer (C-Lock, Inc., Rapid City, SD, USA) with two bunks containing the loose mineral salt and two bunks containing the salt limited protein pellet (Table 1). Target intake rate was 0.085 kg of loose mineral per head per day and 1.4 kg protein pellet/head/day, based on the supplement manufacturers' recommendations for meeting the nutritional requirements of grazing beef cattle. The SmartFeed Pro Trailer was equipped with radio frequency identification (RFID) readers and automatic gates which allowed access to supplement type based on each animal's assigned treatment. SmartFeed Pro system recorded individual daily supplement intake (expressed as kg/day and g/kg BW), intake rate (g/min), and time spent at the feeder (min/day) continuously for 84 days. Bodyweight and BCS were measured on days 0, 28, 56, and 84 following a 16-hr shrink period. Prior to initiation of the study, the SmartFeed unit was programmed to training mode which kept gates in an open position to allow *ad libitum* access to all heifers for a two-week adaptation period.

Table 1. Composition of the protein and/or mineral supplement offered to cattle at Fort Ellis Agricultural Experiment station during the summer grazing period in two consecutive years

	Protein Pellet[1]	Mineral[2]
Crude Protein (%DM)	30.3	----------
Crude Fat (%DM)	1.5	----------
Crude Fiber (%DM)	5.0	----------
Calcium (%DM)	1.2	12.0
Phosphorus (%DM)	0.6	3.1
Salt (%DM)	25.0	25.0
Potassium (%DM)	1.3	0.5
Magnesium (%DM)	0.3	2.7
Manganese (ppm)	56	3,500
Zinc (ppm)	52	7,720
Copper (ppm)	10	2,730
Cobalt (ppm)	----------	25
Iodine (ppm)	----------	300
Selenium (ppm)	----------	36
Vitamin A (IU/kg)	----------	661,380
Vitamin D (IU/kg)	----------	66,138
Vitamin E (IU/kg)	----------	1,102.3

[1] 30-10 25% Salt 3/16 Pellet (CHS, Inc. Sioux Falls, SD, USA 57107). Supplement ingredients: Processed Grain Byproducts, Salt, Plant Protein Products, Molasses Products, Urea, Calcium Carbonate, Sodium Bentonite, Calcium Sulfate, Talc.

[2] 12-2-25+ Chelated Mineral Meal (CHS, Inc. Sioux Falls, SD, USA 57107). Supplement ingredients: Salt, Calcium Carbonate, Processed Grain Byproducts, Monocalcium Phosphate, Dicalcium Phosphate, Magnesium Oxide, Zinc Amino Acid Complex, Manganese Amino Acid Complex, Mineral Oil, Yeast Culture, Sodium Selenite, Zinc Hydroxychloride, Copper Amino Acid Complex, Manganese Hydroxychloride, Ethylenediamine Dihydriodide, Basic Copper Chloride, Vitamin E Supplement, Natural and Artificial Flavors Added, Cobalt Carbonate, Vitamin A Supplement, Vitamin D3 Supplement, Selenium Yeast, Calcium Silicate, Calcium Salts of Long Chain Fatty Acids, Silicon Dioxide.

Cattle were rotated pastures every 2 weeks and forage production and quality were sampled at each pasture entry and exit. Biomass was clipped from ten randomly placed, 0.25-m^2 circular quadrats within each pasture. Biomass samples were dried to a constant weight at 55°C and weighed to the nearest 0.01 g to estimate pasture productivity. Forage samples were ground

with a Wiley Mill and submitted for duplicate analysis of forage quality to Dairy One Laboratories (Ithaca, NY, USA). Forage quality and estimated biomass are displayed in Table 2.

Table 2. Average forage quality of pastures during 28-day long grazing periods over two consecutive summers at Fort Ellis Agricultural Experiment Station.

	Biomass (kg/ha)	TDN[1] (%DM)	CP[2] (%DM)	NDF[3] (%DM)	ADF[4] (%DM)
Year 1					
Period 1	5,460	61.7	6.1	54.7	34.5
Period 2	3,925	60.7	5.2	58.2	39.4
Period 3	4,636	60.0	4.8	60.5	41.9
Year 2					
Period 1	1,926	56.25%	5.75%	62.4	39.3
Period 2	1,688	57.25%	7.4%	58.2	38.7
Period 3	1,759	57.25%	7.425%	59.7	39.4

[1]TDN = Total Digestible Nutrients; [2]CP = Crude Protein; [3]NDF = Neutral Detergent Fiber; [4]ADF = Acid Detergent Fiber. Values are averaged from composite pasture samples analyzed by NIRS (Dairy One Laboratories, Ithaca, NY, USA).

Individual daily supplement intake (kg/d and g/kg BW), variation in supplement intake (CV, %), intake rate (g/min), and time spent at the SmartFeed Pro feeder (min/day) were analyzed as repeated measures using generalized linear mixed models in an ANOVA framework. Each individual animal was considered one experimental unit. Animals removed from the dataset (“non-feeders’) consumed less than 1 kg protein supplement over the entire study (n=14) and less than 0.2 kg mineral (n=13). Animals offered both supplements had to meet both conditions to be removed from the analysis (n=4). The generalized linear mixed model included the fixed effects of treatment, period, year, and their interactions (treatment × period, treatment × year, period × year, and treatment × period × year), and a random intercept for individual heifer to account for repeated measurements. Statistical significance was declared at $\alpha = 0.05$. When significant effects were detected, means were separated using the Tukey method. Linear and quadratic

effects for each analysis were determined using orthogonal polynomial contrasts. All statistical analysis were performed in R (R Core, Inc.).

Results

There was no effect of supplement treatment on ADG ($P \geq 0.58$). Across both years, ADG and BCS change showed a period × year interaction ($P < 0.01$), with the greatest BW increase observed in period 2 and lowest BW gains in period 3. In year 1, heifers gained 32.69 kg (SE ± 2.34 kg) on average while gains in period 3 decreased to 10.91 kg (SE ± 2.39). In year 2, weight gains were more consistent across periods, averaging 21.76 kg (SE ± 2.17). No treatment × period interaction was detected, indicating similar performance trends among all supplement treatments. Average BCS change across the study was ± 0.05 (SE ± 0.06).

All mineral intake metrics displayed a treatment × period × year interaction ($P < 0.01$). In year one, heifers consuming both salt-limited protein and mineral supplements displayed a quadratic decrease in loose mineral intake (kg/d; $P < 0.01$) across periods, while heifers provided only mineral supplement displayed a quadratic increase ($P < 0.01$) in intake across periods (Figure 1). Additionally, heifers consuming both supplements had greater mineral intake in period 1 ($P < 0.01$) but lower intake in periods 2 and 3 ($p < 0.01$) compared to heifers only consuming mineral supplements. In year two, there was no period effect on mineral intake of the heifers consuming mineral-only ($P \geq 0.12$); while heifers receiving both supplements exhibited a linear increase in mineral intake over time ($P < 0.01$). However, for all three periods of year two, mineral-only heifers had greater mineral intake than heifers receiving both supplements ($P < 0.01$).

Similarly, mineral intake expressed as g/kg BW increased quadratically for mineral-only heifers ($P < 0.01$) and decreased quadratically for heifers receiving both supplements ($P < 0.01$) in year one. Heifers consuming both supplements had greater mineral intake per unit BW in period 1 ($P < 0.01$), but mineral only heifers consumed more mineral per unit BW in periods 2 and 3 ($P < 0.01$) In year two, mineral intake per unit BW decreased linearly for mineral-only heifers and increased linearly ($P < 0.05$) for heifers receiving both supplements. For all three periods in year two, mineral only heifers had greater mineral intake per kg BW compared to mineral intake of heifers receiving both supplements ($P <0.01$).

Mineral intake variation (% CV) decreased quadratically for mineral-only heifers over time ($P < 0.01$) and increased linearly for those consuming both supplements ($P < 0.01$) in year one. In period 1, mineral-only heifers had greater variation in mineral intake than heifers receiving both supplements ($P < 0.01$); in period 2, variation in mineral intake did not differ ($P \geq 0.16$) between treatments; and in period 3, heifers consuming both supplements exhibited greater variation in mineral intake than heifers receiving mineral only ($P < 0.01$). In year two, no differences in CV were detected between treatments across periods ($P \geq 0.05$).

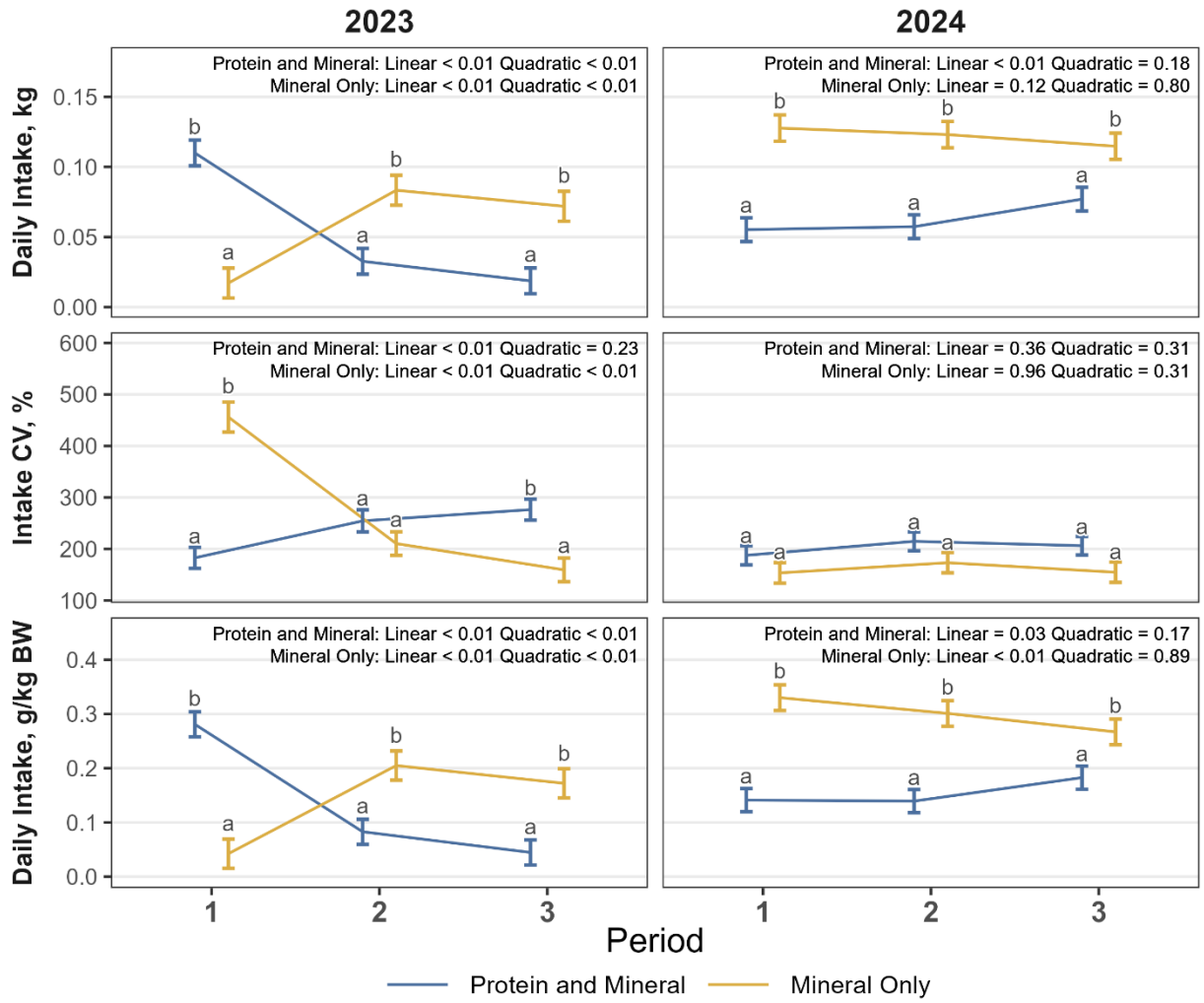


Figure 1. The effects of offering 1) 25% salt protein supplement and 25% loose mineral supplement or 2) 25% loose mineral supplement on daily intake of trace mineral (g/day, top row), trace mineral intake variation (CV, %, middle row), and trace mineral intake per unit BW (g/kg BW, bottom row) across three periods over two consecutive summer grazing seasons.

Time spent at supplement bunk (min/d) increased quadratically for mineral-only heifers in year 1 ($P < 0.01$) and decreased quadratically for heifers receiving both supplements ($P < 0.01$). In period 1, heifers receiving both salt-limited supplements spent more time at the feeder than mineral-only heifers ($P < 0.01$), where in periods 2 and 3, mineral-only heifers spent more time at the feeder ($P < 0.01$) than heifers receiving both supplements. In the second year of the

study, there was no period effect on time spent at feeder for heifers consuming mineral alone, however, heifers receiving both supplements exhibited a linear increase in time spent at the feeder. For all three periods of year 2, heifers receiving both supplements spent more time at the supplement feeder ($P < 0.01$) compared to heifers receiving mineral only.

Loose mineral intake rate (g/min) in year 1 displayed a linear increase for mineral-only heifers ($P < 0.01$) and a quadratic decrease for heifers receiving both supplements across periods in year 1 ($P < 0.01$). Heifers receiving both supplements consumed loose mineral at a faster rate of 4 g/minute (SE ± 0.4 g/minute), compared to mineral-only heifers that consumed 5 g/minute (SE ± 0.5 g/minute) in period 1 of year 1 ($P < 0.01$). In periods 2 and 3 of year 1, there was no treatment effect on mineral supplement intake rate ($P \geq 0.06$). In year 2, mineral intake rate displayed a linear decrease by mineral-only heifers ($P < 0.05$) and by heifers receiving both supplements ($P < 0.01$). In year 2, there was no significant treatment effect on mineral intake rate ($P \geq 0.06$).

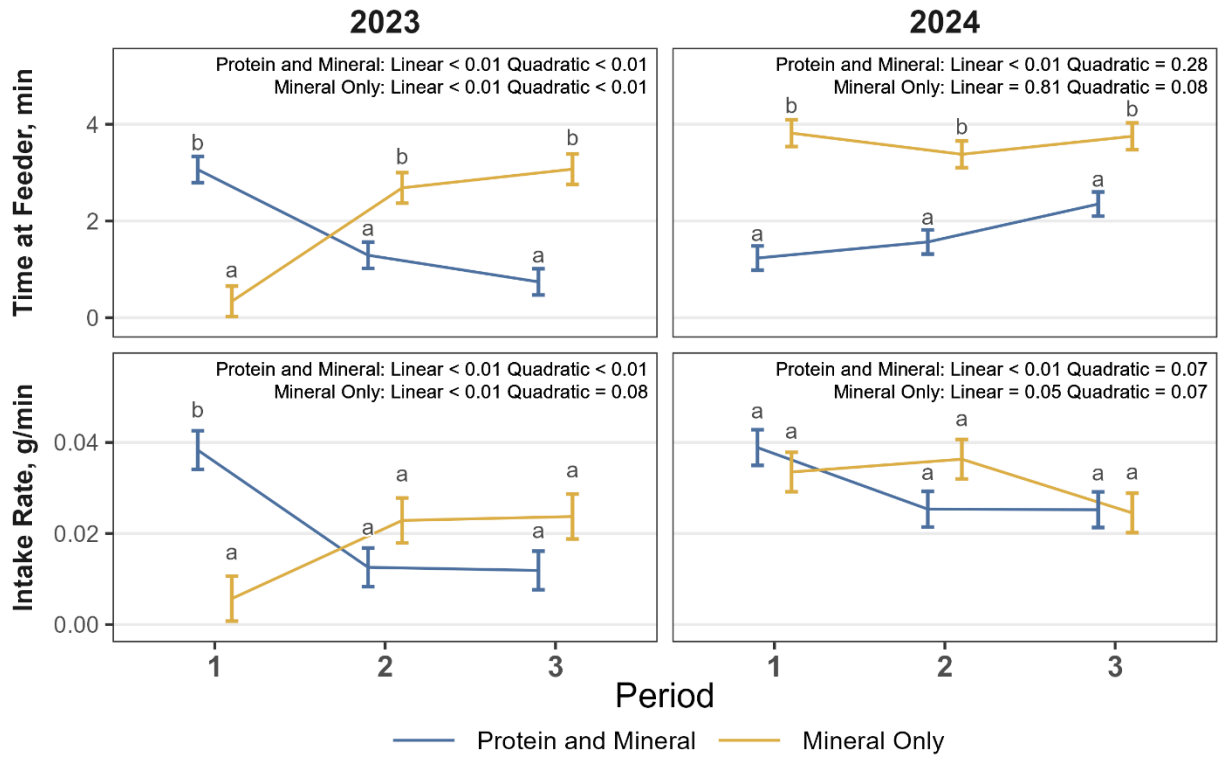


Figure 2: The effects of offering 1) 25% salt protein supplement and 25% loose mineral supplement or 2) 25% loose mineral supplement on time spent at loose mineral feeders (minutes, top row) and loose mineral intake rate (g/min, bottom row) across three periods over two consecutive summer grazing seasons.

All metrics of protein intake displayed a treatment × period × year interaction ($P < 0.01$). In year one, protein supplement intake kg/d increased quadratically for both treatment groups. In period 1, protein-only heifers had greater daily intakes than heifers allowed both salt-modulated supplements ($P < 0.01$), however, 3there was no treatment effect on daily protein intake ($P \geq 0.71$) in periods 2 and 3. In year 2, protein intake increased quadratically for both treatment groups ($P < 0.01$). There was no treatment effect on protein intake in year 2 ($P \geq 0.80$)

Daily protein supplement intake expressed as g/kg BW increased quadratically for both treatment groups in year 1 ($P < 0.01$). In period 1, protein-only heifers had greater protein intake ($P < 0.01$), averaging 1.63 g/kg BW (SE ± 0.31 g/kg BW) than heifers consuming both salt-

limited supplements, which averaged 0.39 g/kg BW (SE ± 0.23 g/kg BW), however, in periods 2 and 3 there was no treatment effect on protein intake ($P \geq 0.20$), averaging 3.038 g/kg BW (SE ± 0.31 g/kg BW). In year 2, protein intake by both treatment groups increased quadratically over time ($P < 0.01$), with no treatment effects on protein supplement intake ($P \geq 0.20$). Year two protein intake averaged 1.15 g/kg BW (SE ± 0.22).

Protein intake variation, expressed as % coefficient variation, displayed a linear decrease by protein-only heifers ($P < 0.01$) and a quadratic decrease by heifers consuming both salt-modulated supplements across periods in year 1 ($P < 0.01$). In period 1 of year 1 heifers consuming both supplements had a greater CV (348.53 %; SE ± 21.72 %) than protein-only heifers (158.95 %; SE ± 28.87; $P < 0.01$), while in periods 2 and 3, there was no treatment effect on intake CV, averaging 116.84 % (SE ± 28.87%; $P \geq 0.23$). In year 2, there was no period effect on intake CV for either treatment group ($P \geq 0.40$) and no treatment effect on protein intake CV ($P \geq 0.27$), averaging 136.77 % (SE ± 20.00 %).

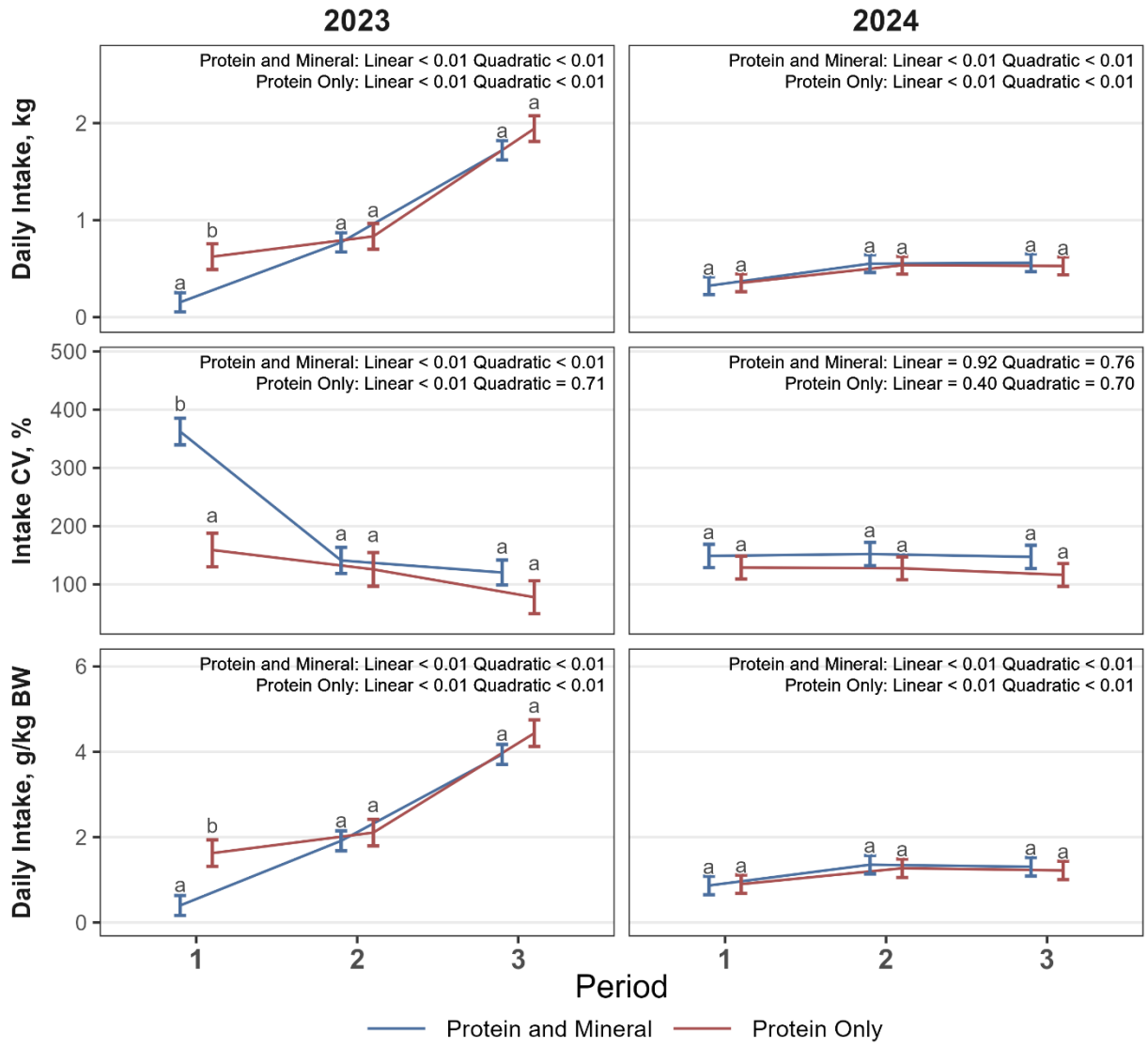


Figure 3: The effects of offering 1) 25% salt limited protein supplement and 25% salt loose mineral or 2) 25% salt limited protein supplement only on protein supplement daily intake (g/day, top row), intake variation (CV, %, middle row), and intake per unit BW (g/kg BW, bottom row) across three periods over the summer grazing season over two consecutive years.

Time spent at the protein supplement feeder (minutes) increased quadratically over time by protein-only heifers in year 1 ($P < 0.01$). Heifers consuming both supplements displayed a linear increase in time spent at the protein feeder in year 1 ($P < 0.1$). In period 1, year 1, the protein-only treatment spent more time at the protein supplement bunk than the protein- and

mineral- treatment ($P < 0.01$), however, in periods 2 and 3, there was no treatment effect on time spent at feeder ($P \geq 0.31$). In year 2, time spent at feeder showed a linear increase for protein-only heifers ($P < 0.01$) and increased quadratically for the heifers receiving both salt-limited supplements ($P < 0.01$). However, there was no treatment effect in periods 1, 2 or 3 of year 2 on time spent at feeder ($P \geq 0.56$).

Intake rate of protein supplement in year 1 showed a linear increase for both treatment groups ($P < 0.01$). In period 1 of year 1, intake rate by the protein-only treatment was greater than the treatment group receiving both supplements ($P < 0.01$) averaging 9 g/minute (SE ± 1 g/minute) for protein only heifers and 2 g/minute (SE ± 1 g/minute) for heifers receiving both supplements. In periods 2 and 3 there was no treatment effect on protein supplement intake rate ($P \geq 0.07$), averaging 12 g/minute (SE ± 1 g/minute). In year 2, there was no period effect on protein supplement intake rate for either treatment group ($P \geq 0.29$) and no treatment effect on protein supplement intake rate ($P \geq 0.33$), averaging 9 g/minute (SE ± 1 g/minute).

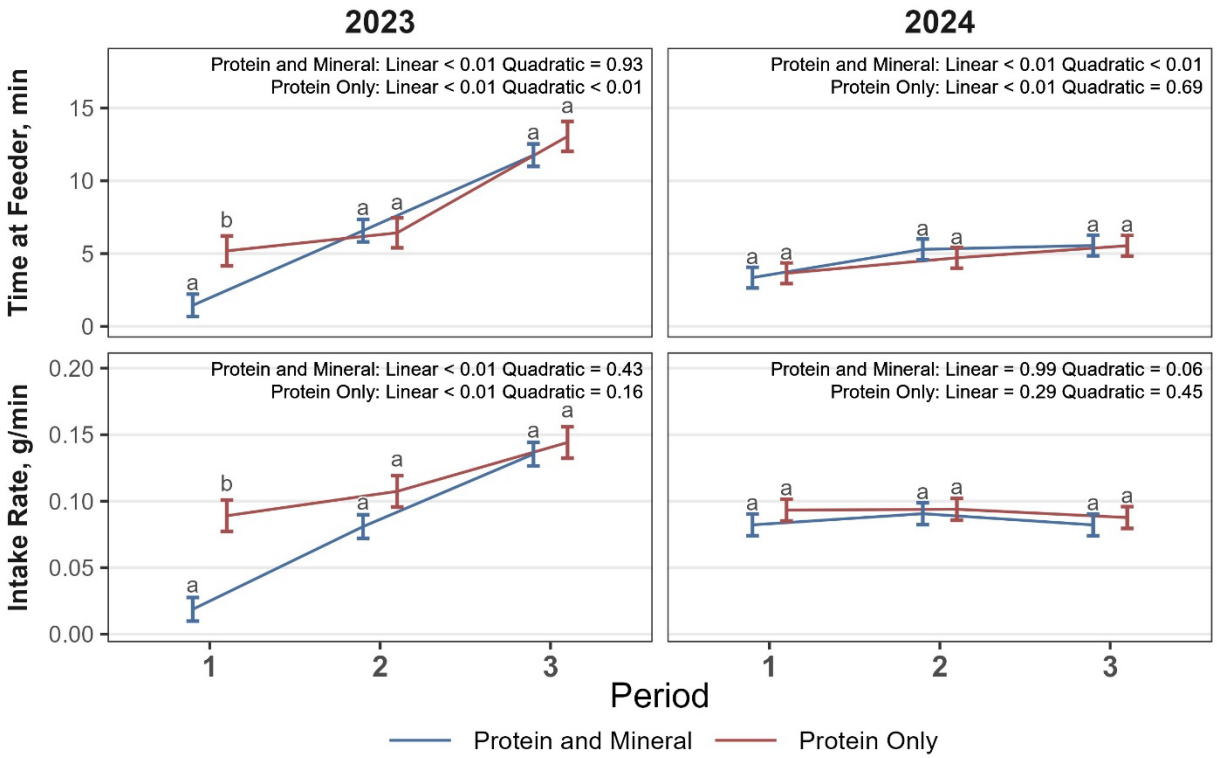


Figure 4. The effects of offering 1) 25% salt protein supplement and 25% loose mineral supplement or 2) 25% salt protein supplement only on time spent at protein supplement feeder (minutes, top) and protein supplement intake rate (g/min, Bottom row) across three periods over two consecutive summer grazing seasons.

Discussion & Implications

Our study indicates that offering multiple salt-limited supplements can influence the intake and intake behavior of heifers consuming salt-limited supplements. We observed that heifers consuming both salt-limited supplements generally had lower mineral intake than heifers consuming mineral supplement alone.

In year one, a quadratic increase in voluntary protein intake coincided with a quadratic decrease in mineral intake by heifers consuming both supplements. The observed pattern aligns partially with the theory that cattle adapt to dietary salt levels and increase intake over time

(Kunkle, 2000; Parsons et al., 2021; Wyffels et al., 2021; White et al., 2024); however, stable intakes observed in year two contradict this; perhaps due to differing forage or summer/fall conditions. In year two, stable forage quality and consistent protein supplement intake were observed across periods. Heifers receiving both salt-limited supplements maintained mineral intake below that of mineral-only heifers, even under differing forage conditions. Thus, the data suggest that offering a salt-limited protein supplement may suppress the intake of a salt-containing mineral supplement regardless of forage quality variation.

In addition to differing forage conditions in the summer/fall grazing season between the two years of this study, heifers in year one had a shorter adaptation period (14 days) to the supplement bunk, in which all four bunks were filled with protein supplement. In year two, due to supplement feeder technical difficulties, heifers were allowed an additional 14 days in which feeder was programmed to training mode. The first 14-days of training mode in year two, all four bunks were filled with protein supplement. During the latter 14-day period, two of the four bunks were emptied, calibrated, and filled with the loose trace mineral. Therefore, heifers in year two had a period of adaptation to both the automatic feeder and both supplements. In year one, there appears to be an artifact in the intake and intake behavior data of period one. We did not see the same effect in year two. This suggests that future studies utilizing automatic feeders consider an adaptation period for both the supplement delivery mechanism and feed treatments to avoid neophobia during the early monitoring period.

Prior to the statistical analysis, non-feeders were removed from the dataset. Heifers that were locked out of either the protein or trace mineral supplement bunks amounted to 14 and 13 individuals, respectively. Meanwhile, the group of heifers that had access to both the protein and

mineral supplement bunks had 4 non-feeders. This suggests that preventing access to a supplement bunk may coincide with a higher proportion of non-feeders which is a critical factor for future studies utilizing automatic feeders with locking headgates.

The supplement manufacturer's target mineral intake rate was 85 g/day. In year one, mineral-only heifers averaged 17, 83, and 70 kg/day (SE ± 10 g/day) in periods 1, 2, and 3, respectively. Heifers consuming both salt-limited supplements averaged 11, 30, and 20 g/day (SE ± 10 g/day). In year two, mineral-only heifers averaged 130, 120, and 110 g/day (SE ± 10 g/day), while those receiving both supplements consumed 50, 50, and 70 g/day (SE ± 8 g/day) in periods 1, 2, and 3, respectively. Besides period 1 of year 1, daily mineral intakes by heifers receiving both supplements were generally below the prescribed mineral intake target, while mineral-only heifers were within the margin of error, or exceeding target mineral intake. Neophobia (Forbes, 1995) can be characterized as a period of low feed intake, followed by an increase in intake, followed by stable intakes (Bowman and Sowell, 1997). This may explain the temporal pattern of mineral supplement intake exhibited by mineral-only heifers in year one, however, all animals had an adaptation period prior to study initiation.

Overall, depressed mineral intake by heifers consuming both salt-containing supplements suggests that the presence of a salt-limited protein supplement coincided with animals not meeting daily target mineral intake to meet nutrient requirements. Cockwill and others (2000) observed a similar preference in which cows and heifers offered only a protein-molasses block had more visits to the feeder and greater intake amounts than individuals only offered a mineral supplement. Furthermore, previous work (Embry et al., 1959) demonstrated reduced mineral intake when NaCl was added to drinking water. Our findings similarly indicate that concurrent

salt sources may depress voluntary mineral consumption. Overall, our results suggest that when salt provided through another dietary source (e.g., protein supplements), mineral intake is reduced, potentially below target intake rates.

Differences in mineral intake did not influence BW gain or BCS during the monitoring period. Multiple studies (Manzano et al., 2012; Dixon et al., 2003; Eggington et al., 1990) also observed no relationship between mineral intake and bodyweight change. Furthermore, McCarthy and colleagues (2021) found that both high- and low- mineral consuming cows were within adequate ranges for liver mineral concentrations of Se, Cu, Co, Fe, Zn, Mo, and Me (Kincaid, 2000), but that individuals consuming high levels of mineral (> 0.09 kg/day) had greater liver concentrations of minerals Se, Cu, and Co than cows consuming low mineral (< 0.05 kg/day), suggesting that animals consuming high amounts of mineral are able to store reserves of these minerals (McCarthy et al., 2021). While our study did not measure liver or blood concentration of minerals, chronic mineral deficiency could have long-term production consequences.

The CV for daily mineral intake was high, like other mineral intake studies (Cockwill et al., 2000; Manzano et al., 2012; Dixon et al., 2001). We observed that higher mineral intakes had lower variation while lower intakes had higher variation, however, mineral intake variation across treatments, periods, and years remained high across individual animals and over time within individual animal. Due to small intake amounts, mineral intake generally exhibits high variation (Tait and Fisher, 1996). Mineral supplementation constitutes a significant cost in beef operations, and inefficient intake can undermine performance outcomes. While supplement treatment generally did not influence protein intake, forage quality appeared to decrease

overtime in year one, corresponding with a quadratic increase in voluntary protein intake by heifers consuming protein supplement. In year two, forage quality remained stable, coinciding with protein intakes that did not differ over time. The supplement manufacture's recommended daily intake for the protein pellet was 1.4 kg/head/day. In year 1, protein-only heifers consumed 0.62, 0.83, and 1.94 kg/day (SE ± 0.13) and heifers consuming both supplements consumed 0.15, 0.77, and 1.72 kg/day (SE ± 0.10) in periods 1, 2, and 3, respectively. In year 2 protein-only heifers consumed 0.35, 0.53, 0.52 kg/day (SE ± 0.09) and heifers consuming both supplements consumed 0.32, 0.55, and 0.56 kg/day (SE ± 0.09) in periods 1, 2 and 3, respectively. In summary, our results indicate that the presence or absence of a loose mineral salt did not influence protein supplement intake, suggesting that animals may prioritize a palatable salt-limited supplement over mineral salt.

From a management standpoint, producers should consider total dietary salt load from forage, stock water, and supplements. Offering multiple salt-limited products can lead to underconsumption of minerals and economic loss. Combining protein and mineral into a single supplement may improve the ability to deliver more balanced nutrient profile, and monitoring environmental salt sources and removing a plain salt supplement can help producers adjust supplementation strategies (Arthington and Ranches, 2021). It is important to note, however, that our study, among others, display high intake variability in daily protein supplement intake. Studies that examine the differences between daily – once weekly hand feeding of protein supplement show no difference in terms of animal performance benefits (McIlvain and Shoop, 1962; Pope et al., 1962; Wallace, 1988; Coleman and Wyatt, 1982; Kunkle et al., 2000). Therefore, as long as individuals consume protein supplement in a manner that fulfills their

requirements on a weekly basis, utilizing a palatable protein supplement as a carrier for trace mineral nutrition may offer a promising avenue for strategic supplementation, and future research should examine this approach to improve supplementation for grazing operations influenced by mineral and nitrogen-deficient forages.

CONCLUSION

Harvested forages, grain, protein, and mineral supplements account for 35-40% of variable cash costs in beef production in the Great Plains (Economic Research Service, 1995; Adams et al., 1996; Economic Research Service, 2025). Because supplemental feeding represents a major expense, improving supplement formulation, delivery, and uniformity of intake remains critical for profitability. Many protein and mineral supplements rely on the inclusion of salt to modulate intake, however to our knowledge there was no information pertaining to supplement selection when multiple supplements utilized the same intake modulator. We wanted to know if multiple supplements, utilizing salt, competed in terms of supplement intake.

To answer this question, we designed an experiment to compare the intake behavior and performance of heifers with access to two salt-containing supplements, to those that only had access to a salt-limited protein or trace mineral salt. By measuring intake continuously for 84 days over two consecutive years, we learned that offering multiple salt-containing supplements does appear to depress mineral supplement intake below target rates.

We observed that offering a salt-limited protein supplement alongside a salt-limited mineral supplement reduced mineral intake below manufacturer target intake levels. However, the presence of the mineral supplement did not significantly alter protein intake. The effect appears asymmetric, where protein intake is stable, but mineral intake declines when multiple salt sources are present. This finding supports the idea that cattle self-regulate total salt intake (Kunkle et al., 2000). Once that salt threshold is met, heifers appeared to prioritize the palatable protein supplement over the mineral salt. This selective behavior could be driven by numerous

factors, including taste preference, social hierarchy, and adaptation to salt concentration and future research should further investigate these physiological and behavioral dynamics as they relate to salt satiety. Importantly, while animal performance did not differ during the 84-day monitoring period, prolonged suboptimal mineral intake could have cumulative effects on reproduction, immunity, and long-term productivity.

These findings emphasize that managing total dietary salt load – including contributions from water, forage, and multiple salt-limited supplements – must be considered in formulation and feeding decisions. Our results demonstrate that multiple salt-limited supplements can suppress mineral intake below manufacturer targets. Future research should quantify mineral status responses (e.g., plasma or liver concentrations) and animal performance implications to confirm the physiological effects of reduced intake in response to offering multiple salt limited supplements. Another opportunity would be to test whether spatial or temporal separation of supplement sites, or alternative intake limiters, could reduce variability and improve consistency in mineral consumption. Finally, a study investigating intake behavior of a pellet containing trace mineral and protein and subsequent animal performance may improve the ability for producers to offer self-fed supplements to grazing beef cattle.

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