Effects of biuret and lasalocid (Bovatec) inclusion into a commercial mineral supplement on growth performance of yearling calves grazing in the Kansas Flint Hills

by

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Abstract

Research has demonstrated that using biuret has improved performance in grazing cattle. Lasalocid (Bovatec^{TM}), an ionophore, has improved the growth performance of grazing cattle and reduced methane production in growing and finishing cattle. The objective of our experiment was to evaluate the effects of biuret inclusion with and without lasalocid in a commercial mineral mix on the growth performance of yearling beef calves grazing in the Kansas Flint Hills. Over a 2-year period, 742 crossbred steers (initial body weight: 297 ± 23.7 kg) previously backgrounded at the Kansas State Beef Stocker Unit were randomly assigned to one of three mineral treatments (control mineral, control mineral with biuret, and control mineral with biuret + lasalocid). Pastures were previously enrolled in a long-term prescribed fire trial. In the experiment, 18 pastures were blocked by prescribed fire treatment and mineral treatments were assigned randomly to pasture with each mineral treatment represented twice within each prescribed fire treatment. Steers were grazed from May to August for 90 days at a targeted stocking density of 280 kg live-weight ⋅ ha^{-1}. Mineral feeders were weighed weekly to determine mineral consumption and refilled weekly with the respective mineral treatment at a target consumption of 113.4 g per head daily. In addition, mineral feeders were checked daily to estimate the number of days until an individual mineral feeder was empty (i.e., days-to-empty). Total body weight gains, average daily gains and mineral consumption did not differ ($P \leq 0.15$) among mineral treatments. Final body weights were greater ($P \leq 0.03$) for biuret and biuret + lasalocid mineral compared with control. Days-to-empty varied between weeks ($P \leq 0.01$), with calves consuming mineral at a slower rate at the initiation of the year of the experiment. There also were variations between days-to-empty and mineral treatment ($P \leq 0.02$).

Key Words: grazing, ionophore, mineral, non-protein nitrogen

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Chapter 1 - Review of Literature

Introduction Flint Hills

Tallgrass prairie was once 170 million acres that spanned the Great Plains from Texas through Canada and went as far east as Indiana; however, only 4% remains today due to the advent of tillage agriculture in the plains area (Hickey, 1987; The Nature Conservancy, n.d.). The largest remnant of tallgrass prairie resides in the Flint Hills and is approximately 3.7 million acres stretching across Kansas and into Oklahoma (WHSRN, 2018). The Flint Hills have a variety of soil types including cherty, clay with ridges, thin limestone, steep slopes, shales, and flood plains (Bidwell, 1966). The survival of the remainder Flint Hills is due to the rocky soil structure which was not suitable for plowing and shallow limestone bedrock (Middendorf et al., 2009).

Big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*) comprise about 50 percent of the vegetation in the Flint Hills (Anderson and Fly, 1955). Pastures also include sideoats grama (*Bouteloua curtipendula*)), Indiangrass (Sorghastrum nutans), and swithchgrass (*Panicum virgatum*), along with small amounts of short grasses and forbs that seldom make a major percentage of forage (Anderson and Fly, 1955).

The steep rocky slopes of the Flint Hills made farming the land difficult for European settlers; however, the area was suitable for grazing cattle (Middendorf et al., 2009). Early on, ranchers observed 2-year-old steers grazing Flint Hills pastures could achieved body weight gains between 90 and 135 kilograms in a single grazing season (Anderson, 1953). By the 1920s, the Flint Hills received approximately 400,000 head annually of cattle, primarily from the southwestern United States for the summer grazing season (Isern, 1985). The Pacific Railroad Act was passed in 1862 which allowed large amounts of land to be deeded railroad companies to allow for the construction of the transcontinental railroads (Middendorf et al., 2009; National Archives, 2022). This played an important role in the cattle industry by aiding in the movement of cattle through the region (Middendorf et al., 2009). Cattle were shipped to leased pastures as forage growth began in April or May and grazed and cattle were then shipped when ranchers determined protein levels of the pasture grasses had decreased, or when cattle were ready for market (Middendorf et al., 2009).

Burning

Burning of the Flint Hills began with natural fires from lightning strikes and with the Native Americans who used burning as a dual-purpose practice. Native Americans would have a ceremonial burn for a call of rain and to attract bison to the fresh grass that would sprout after the burn (Isern, 1985). Early settlers in the Flint Hills discovered that cattle tended to graze burned pastures more compared with the non-burned pastures (Anderson et al*.,* 1970). In addition, settlers discovered cattle that grazed burned pastures gained more rapidly than those that grazed non-burned pastures (Anderson et al.,1970). Today, an annual spring-season prescribed fire is typically used by Flint Hill ranchers to increase yearling stocker cattle weight gains, and to limit encroachment of woody or invasive plant species (Anderson et al., 1970).

Ehrenreich (1959) evaluated the effects of burning and clipping on growth habits of plants on Iowa tallgrass prairie. Areas of 1 to 10 acres were burned over three years with treatments including burning only year one, burning only year two, burning only year three, burning only year one and two, burning only year one and three, burning only year two and year three, burning all three years, or not burning at all. Samples were clipped every 4 weeks in years 1955 and 1956 to determine plant growth rate and seed stalk development. Burned areas had earlier growth and produced more flower stalks compared with non-burned areas. Areas burned in years one and two contained approximately 336 kg/ha^{-1} of litter while areas burned in year one contained approximately 1009 kg/ha^{-1} of litter. Conversely, non-burned areas contained approximately 4887 kg/ha^{-1}of litter. In 1955, areas that were burned twice began growing approximately 2-3 weeks before areas burned once; however, forage yield did not differ between burned and non-burned areas. Researchers stated that this was due to the fact that the greater number of flowering stalks in burned areas gave similar yield to the amount of basal leaves on plants in the non-burned areas.

Towne and Owensby (1984) evaluated the effects of prescribed-fire timing on herbage production in the Kansas Flint Hills over a 56-year period. Predominant species were little bluestem (*Schizachyrium scorparium*), prairie junegrass (*Koeleria pyramidata*), big bluestem (*Andropogon gerardii*) and Indiangrass (*Sorghastrum nutans*). Treatments included winter burn (December 1), early-spring burn (March 20), mid-spring burn (April 10), late-spring burn (May 1), and a non-burned treatment. Burn dates varied by year based on weather conditions. In addition, burn treatments were not applied between 1935-1937 and from 1945-1949, which resulted in 49 total burns over a 53-year period. Indiangrass increased when plots were burned in late spring compared with non-burned plots. Little bluestem increased in early and mid-spring burned plots compared with non-burned plots. Basal cover was greatest on plots burned in mid- and early-spring which may have been associated with increased proportions of little bluestem. Little bluestem is a bunchgrass; therefore, increasing proportions of little bluestem in early and mid-spring burned plots may have contributed to the overall increase in the basal cover. Basal cover was less on non-burned plots compared with burned plots. Late spring burning maximized yield of big bluestem and Indiangrass in the Kansas Flint Hills. These results demonstrated that time of burning effected vegetation growth and the use of prescribed fire timing could be useful in increasing forage quality.

Anderson et al. (1970) evaluated the effects the of prescribed-fire timing on weight gains of steers over 17 years. Three 44-acre pastures were burned annually with a 60-acre pasture not burned (control). Pastures were burned from 1950 to 1966 with various burn dates which included early spring burn (March 20), mid-spring burn (April 10), and late spring burn (May 1). Hereford steers were grazed from late April or early May to October averaging 151 days of grazing. Individual weights of steers were obtained at the beginning of each month. Mid- and late-spring burning increased average daily gains compared with the non-burned pasture. Weight gain advantages accrued in May and June. The increased average daily gain in mid- and late-spring could be due to the fact that the burn increased forage quality in the early part of the grazing season (Anderson et al., 1970).

Overall, the use of prescribed fire can be an influential tool in grazing nutrition. When prescribed fire is used forage quality increases, resulting in improved performance of cattle grazing the pasture.

Forage Quality

Knowing the nutritive value of forage is important when determining the appropriate time to provide supplementation to grazing cattle. Forage quality is dependent on many factors, including the amount of protein, minerals, and vitamins in the forage. These factors are influenced by the stage of maturity, edaphic influences, plant species, climate, animal class, and range condition (Oelberg, 1956). The nutritive value of a plant is typically high during the initial stages of growth and begins to decline as the plant matures. As a plant matures, protein and soluble carbohydrates concentrations are reduced, while lignin and silica increase (Fonnesbeck et al., 1975). During the grazing season, when forage maturity is at its greatest, it could be beneficial to provide supplementation to meet the animals' nutrient requirements.

Fiber content is often used as a measure of forage quality. Fiber content can be analyzed multiple ways, and each analytical method determines how fiber is defined (e.g., crude fiber, acid detergent fiber, neutral detergent fiber). Van Soest and Wine (1967) developed an analysis using detergents that removed soluble proteins and soluble carbohydrates, without affecting the mass of fiber in a sample (Huhtanen et al., 2008). Neutral detergent fiber (NDF) is an estimate of total cell wall content (i.e, cellulose, hemicellulose and lignin) and the detergents used split the feed into a soluble fraction that is available and is quickly degraded by microbial enzymes and a fiber fraction that is slowly and not completely degraded by microbial enzymes (Huhtanen et al., 2008; Diatta et al*.,* 2021). Acid detergent fiber (ADF) measures lignin, cellulose, silica, and insoluble forms of nitrogen (Novotny et al*.,* 2017). Since hemicellulose, cellulose and lignin help with cell strength and rigidity of the cell, they are referred to as structural carbohydrates (Moore et al., 2001). Lignin, which is considered poorly digestible, serves as a structural component in the cell wall.

Mowat et al. (1969) collected grasses and legumes at three different stages of maturity: early (vegetative), medium (heads emerged, in flower), and late (seed). Analyses were run using Van Soest and Wine (1967) methods to determine acid detergent fiber (ADF), permanganate lignin, cellulose, silica, and cell wall constituents. Using the method used by Tilley and Terry (1963), they evaluated *in vitro* cell wall digestibility and determined that as plant maturity increased, cell wall digestibility decreased. Lignin showed the highest correlation with cell wall digestibility, as lignin content increased as cell wall digestibility decreased. With increasing lignin content in the diet there will be a reduction in passage rate, and a decrease in consumption (Moore et al., 2001).

In conclusion, determining forage quality is an important activity that ranchers can do to understand when it is necessary to supplement the nutrients, such as protein, to grazing cattle. As the plant matures, fiber and lignin content will increase, while protein and mineral content decrease. When the animal requirements are not being met, growth performance will be reduced.

Minerals

Minerals play an important role in the maintenance of normal body functions. Minerals have structural, physiological, catalytic, and regulatory functions in the body. Minerals can be structural by forming components of the body, such as the use of calcium in bones. Physiological uses are related to acid-base balance or maintenance of osmotic pressure. Catalytic uses refer to minerals that act as catalysts for enzymatic reactions. Finally, regulatory minerals are those that regulate cell replication and differentiation. An example of a regulatory mineral would be zinc, as it is involved in transcription (Underwood and Suttle, 1999). Animal response to mineral deficiencies or toxicities depends on a minerals specific function (Weiss and Spears, 2006).

The maintenance requirement is the daily intake level that is required to support functions such as respiration, circulation, and other functions related to basal metabolism (Underwood and Suttle, 1999). The mineral requirements of animals are variable and dependent on productive function, age, and sex (Sewell, 1914). Minerals can be divided into two groups: macro-minerals and micro-minerals. Micro-minerals are also referred to as trace minerals. Macro minerals are required in greater amounts compared to micro-minerals (Paterson and Engle, 2005). Seven macro-minerals are required by ruminants for growth and maintenance: calcium, phosphorus, sulfur, potassium, magnesium, sodium, and chloride (Ward and Lardy, 2005; Ning et al., 2022).

Ten micro-minerals are required by ruminants which include cobalt, chromium, copper, iodine, iron, manganese, molybdenum, nickel, selenium, and zinc (Paterson and Engle, 2005; Arthington and Ranches, 2021).

Mineral Requirements

Calcium plays a key role in muscle function such as muscle contractions and is a major mineral in both bone and teeth (Lalman and McMurphy, 2004; Ward and Lardy, 2005). Calcium also plays a role in blood clotting, heartbeat regulation, hormone secretions, and milk production. Calcium is also the most abundant mineral in the body (Perry 1995). Calcium is recommended at 0.36% of the diet for growing cattle but is variable on animal production (NRC, 1996). Phosphorus also is a major mineral in bone; however, it also plays a key part in major metabolic functions such as protein and fat metabolism (Ward and Lardy, 2005). Phosphorous is also involved in energy transfer through adenosine triphosphate (ATP) (Perry, 1995). Phosphorus is recommended at 0.19% of the diet for growing cattle, which is also variable dependent on the physiological state of the animal (NRC, 1996). Calcium and phosphorus in the diet are recommended to be supplied at a ratio between 1.5:1 and 2:1 (Ward and Lardy, 2005). Calcium is typically adequate in forages; however, concentrations decrease when forage matures (Lalman and McMurphy, 2004; Ward and Lardy, 2005;). In contrast, phosphorus is usually deficient in forages (Ward and Lardy, 2005). Providing a supplement with a lesser ratio of calcium phosphorus is beneficial for grazing cattle.

Sulfur is typically recommended at 0.15% of the diet in grazing cattle. Sulfur is the only mineral used in amino acids that construct protein (Ward and Lardy, 2005). Conversely, when dietary concentrations are high in sulfur, polioencephalomalicia (PEM) can occur, leading to death (Lalman and McMurphy, 2004).

Potassium works as an acid-base balance, regulating osmotic pressure and muscle contractions; it is involved in some enzyme reactions as well (Lalman and McMurphy, 2004). Potassium is recommended at 0.7% of the diet and is typically adequate in forages (Ward and Lardy, 2005).

Magnesium is important in many metabolic enzymes and has a role in the central nervous system support. Magnesium is also closely related to calcium and phosphorus in its functions. Grass tetany can occur when magnesium is deficient (Lalman and McMurphy, 2004; Martens, 2018) and deficiencies may cause decreased feed intake and even death (Mayland, 1988). Magnesium is recommended at 0.1 percent of the diet (Ward and Lardy, 2005). Sodium and chloride are usually considered together as they play a key role in the osmolarity and pH of cells. Sodium chloride (salt) intake is recommended at 11 to 15 grams daily (Ward and Lardy, 2005).

Cobalt, chromium, copper, iodine, iron, manganese, molybdenum, nickel, selenium, and zinc are the ten microminerals that are required by ruminants (Paterson and Engle, 2005; Arthington and Ranches, 2021). Only seven of the ten microminerals have an established requirement for cattle. Those that have an established requirement include iron, manganese, copper, zinc, selenium, cobalt, and iodine (Stewart, 2010). Cobalt is important in providing substrates for the synthesis of vitamin B12 and is recommended at 0.10 to 0.15 mg/kg of DM (Ward and Lardy, 2005; Arthington and Ranches, 2021).

In 2009, the FDA allowed chromium supplementation but only through chromium propionate at levels up to 0.50 mg Cr/kg of diet (Spears, 2010). Chromium plays a role in metabolism and is recommended at 0.3 to 1.6 mg/kg of diet (Khan et al*.,* 2012). Chromium boosts the action of insulin (Weiss and Spears, 2006).

Copper is one of the most commonly deficient micro-minerals in grazing cattle. Its inclusion rate is recommended at between 8 to 10 mg Cu/kg of diet DM. Copper has gut-level antagonists such as sulfur, molybdenum, and iron (Arthington and Ranches, 2021). Antagonists may block absorption of the mineral (Lalman and McMurphy, 2004). Copper is also involved in bone development and amino acid metabolism (Weiss and Spears 2006).

Iodine is a key part of thyroid hormones and is recommended at 0.5 ppm of the diet DM (Lalman and McMurphy, 2004; Ward and Lardy, 2005). Deficiency is rare in common practices when supplementing salt due to iodine fortification in the salt (Arthington and Ranches, 2021).

Iron plays a major role in protein structure; a large portion of iron is found in hemoglobin. Iron is recommended at 50 mg/kg of diet DM (Lalman and McMurphy, 2004; Humann-Ziehank, 2016).

Manganese is related to skeletal cartilage integrity, with links it to growth, and is recommended at 20 ppm for growing and finishing cattle (Ward and Lardy, 2005). Levels are commonly adequate in forages, so manganese deficiencies are somewhat rare in grazing cattle (Arthington and Ranches, 2021).

Molybdenum acts in an oxygen transfer reaction for some enzymes and is recommended at 0.1 ppm of diet DM (Perry, 1995; Hall, 2018). Nickel activates enzymes that are related to utilization and or breakdown of proteins, lipids, and carbohydrates (Singh et al*.,* 2021). It is recommended to not exceed 50 mg/kg of diet DM (Arthington and Ranches, 2021).

Selenium is the most deficient micromineral in cattle consuming forages (Stewart, 2010). Selenium boosts immune function and is recommended between 0.1 and 0.3 mg/kg of diet DM. The FDA states that feed should not exceed 0.3 mg/kg of selenium as it is potentially toxic (Stewart, 2010; Arthington and Ranches, 2021).

Zinc is a cofactor in proteases and RNA and DNA polymerase and is also involved in gene expression and numerous metabolic enzymes (Lalman and McMurphy, 2004; Weiss and Spears, 2006). Grazing cattle are commonly deficient in zinc and the recommended level is 30 mg/kg of diet DM (Arthington and Ranches, 2021).

Factors Affecting Mineral Content

Grazing cattle receive their minerals from the forages that they consume and the concentrations of those minerals in the forage are dependent on several different factors. Those factors include the mineral content of the plant, species of the plant, soil type where the plant grows, climate, season, and maturity stage of the plant (Underwood and Suttle, 1999). The capability of minerals in the forage to meet the requirements of herbivores is dependent on the concentration and bioavailability.

Metson and Saunders (1978) evaluated the effects of season on mineral composition in forages. Samples were taken from 7 different sites with varying soils and climates. The sites were in Hawke's Bay, Wairarapa, and Wellington districts of North Island, New Zealand. Calcium concentrations were greater in clovers compared to grasses. Maximum levels in both clovers and other grasses occurred in summer and late spring. Minimum levels in both clovers and grasses occurred in late spring and mid-winter. Magnesium levels were similar between grasses and clovers. Maximum levels were observed in summer and minimum levels in winter. Potassium levels were also similar between clovers and grasses, with levels being at a maximum in the summer and at a minimum in the winter. Potassium levels were more inconsistent month-to-month compared to other minerals. Metson and Saunders (1978) perceived this to be due to the potassium from urine that was released by the cattle grazing in the pasture.

Sodium similarly had a random seasonal pattern. Sodium concentrations fluctuated throughout the season. Phosphorous, on the other hand, had consistent seasonal patterns with maximum values in the late autumn and early spring; however, there was little variation between maximum and minimum levels (Saunders and Metson, 1971; Metson and Saunders, 1978).

Fleming and Murphy (1968) evaluated the effects of maturity on the content of minerals in grasses over two years. Four types of grass were evaluated: white clover, perennial ryegrass, timothy, and tall fescue. Stages included 2-3 leaf, 4-5 leaf, pre-heading, early heading, full flower, and senescence. Nitrogen levels dropped once the plants approaching heading. When the plant entered the heading stage, nitrogen levels stabilized. These levels only decreased slightly once the plant entered the senescence stage. Phosphorous followed a temporal pattern similar to nitrogen, with a constant decline until the plant entered the heading stage.

With increasing maturity, potassium levels fell until the full-flower stage where levels stabilized. Over the two years, calcium concentration was variable. In the 1st year, calcium increased until the heading stage. In the 2nd year, there was a dramatic decrease in calcium during the 3-4 leaf stage of the plant that lasted util the pre-heading stage. The authors attributed the difference between years to variations in weather.

Magnesium and zinc concentrations changed little with increasing maturity, whereas sodium and copper levels decreased with increasing maturity. Cobalt and molybdenum also decreased as the plant matured (Fleming and Murphy, 1968).

Plant growth rates decreases with maturity and the time that it takes for the growth rate to decrease depends on the species (Clarkson and Hanson, 1980). When plants first begins to develop, mineral absorption is rapid; however, as plants begin to mature, dry matter production becomes more rapid than mineral absorption. Plant biomass accumulation has the effect of diluting mineral concentrations (Fleming and Murphy, 1968).

Soil and Mineral Relationship

Soil nutrient bioavailability is the term used to describe the soil-plant capacity to supply and absorb nutrients. This occurs through the release of solid nutrients that are in the soil to solution phase. Nutrients then move to the plant root-mycorrhizal system and then are absorbed (Comerford, 1998). Soil affects the availability of most essential plant nutrients through biophysiochemical processes which are functions of both soil and plant properties (Comerford, 2005). Soil pH and redox potential, texture, organic matter, mineral composition, temperature, and soil moisture content influence mineral bioavailability (Kabata-Pendias, 2004).

The process which plants use to absorb minerals from the soil through the plat root-mycorrhizal system can be divided into three steps: movement of minerals from soil to root surface, movement of ions to interior root, and translocation of minerals from root to shoot (Barber, 1962; Comerford, 2005). The movement of minerals in the soil to the plant root-mycorrhizal surface occurs through mass flow or diffusion (Comerford, 2005; Barber, 1962). The means that occur depends on the amount of mineral moving to the root-mycorrhizal and the amount of mineral being absorbed by the root (Comerford, 2005). If more mineral moves through water to the root than the plant can absorb, then the plant will leave minerals at the root. When this takes place, mass flow becomes the dominant process. When mass flow does not supply sufficient minerals, diffusion becomes the dominant process.

A mineral concentration gradient is formed between the soil and root, which the minerals follow into the root (Barber, 1962). Diffusion is a slower process than mass flow and will create depletion zones around the plant's roots (Marschner and Rengel, 2023). Magnesium normally follows mass flow, while potassium, phosphorous and other low-concentration nutrients normally use diffusion in many soil types (Marschner and Rengel, 2023). Another major factor in mineral absorption is root growth. Increased availability of minerals is proportional to the length of the roots as more surface area is available to absorb minerals (Marschner and Rengel, 2023).

When soil moisture is low, mineral uptake by roots decreases. Low moisture content will also decrease root growth (Marschner and Rengel, 2023). Chemical analyses of minerals do not provide adequate information on whether minerals are available to the animal consuming them (McDowell, 1996). Bioavailability is dependent on digestive tract interactions, pH of digestive tract, and mineral solubility (Greene, 1997).

Supplementation

Mineral elements play an important role in various biological functions. Deficiencies may harm animal growth, productivity, and health (Underwood and Suttle, 1999). Forages will not meet the requirements of cattle grazing in all circumstances. Maturity is the phenomenon most responsible for decreased mineral content in forages (Underwood and Suttle, 1999). Minerals can be supplemented to the diets of cattle several different ways; through water, drenching, injection, ruminal boli, mineral blocks, and loose mineral mixtures (McDowell, 1996).

Supplementation of minerals through drinking water works well when only one water source is available to ensure consumption. In contrast, drenching ensures that all animals receive a known amount of minerals; however, the disadvantage to this method is the increased labor costs due to handling cattle. Intramuscular injection of minerals possesses the same advantages and disadvantages of drenching. Rumen preparations involve the use of heavy boli such as Co, Se, or Zn. Dosing of the bolus into cattle will result in gradual release of mineral over an extended period of time. However, problems have been reported when animals regurgitate the mineral bolus (McDowell, 1996).

Free-choice methods of mineral supplementation include lick blocks and loose, granular mineral. Lick blocks are solid compresses of minerals that the cattle lick to retrieve the minerals. The advantage to the block is the simplicity. Most of these products will not degrade appreciably when exposed to precipitation, which normally dissolves loose mineral rapidly. The disadvantage to this method, of supplementation is there is often a 10% decrease in consumption compared to loose mineral. With free choice mineral supplementation, the animal has free access to minerals, which is based on the concept that the animal knows which minerals it requires and will have an appetite to fulfill those needs (McDowell, 1996).

Mineral Supplementation

Gunter and Combs (2019) evaluated the effects of supplementing minerals to growing cattle grazing winter-wheat pasture. Treatments included a control group that received salt only and a treatment group that received a free choice mineral supplement. The mineral supplement contained 15% to 17% Ca and 4% P, 5.5% Mg, 18.5% to 22% NaCl, and 220,500 IU of vitamin A/kg on an as-fed basis. The trace minerals in the supplement included 1,250 mg/kg of Mn, 650 mg/kg of Cu, 2,185 mg/kg of Zn, 22 mg/kg of Se, and 65 mg/kg of I on an as-fed basis. The trial lasted 84 days, with cattle weighed every 28 days. On day 28 and day 56, cattle in the control treatments had average daily gains (ADG) of 0.49 and 0.47 kg/d on days 28 and 56, respectively. Cattle supplied with free-choice minerals had an ADG of 0.8 and 0.71 kg/d on day 28 and day 56, respectively. At the conclusion of the 84-day study, the ADG for the entire grazing period was 0.51 kg/day for the control treatment and 0.73 kg/day for the mineral treatment.

Forage samples were also collected every 28 days to determine mineral concentrations in pasture forage. Concentrations of calcium, phosphorus, sodium, copper, and zinc did not meet the requirements stipulated by NASEM (2016), whereas all other minerals in the forage met the recommended requirements over the grazing period (Gunter and Combs, 2019). This study demonstrates that when mineral concentration in forages do not meet the requirements of cattle, the addition of a mineral supplement can improve performance of the grazing cattle.

Protein Supplementation

Similar to deficiencies in minerals, deficiency in protein will decrease cattle performance. Holderbaum and others (1991) evaluated the effects of protein supplementation on growing steers grazing floralta limpograss (*Hemarthria altissima*), a low-protein forage. Treatments included control group with no supplementation, a low protein supplement (9% CP; OM basis), and a high protein supplement (12% CP; OM basis). Supplements were fed once daily and the grazing period lasted 84 days.

The control steers, which received no supplementation, had an average daily gain of 0.29 kg/day over the grazing periods. Steers fed the low-protein supplement gained 0.53 kg/day and steers fed the high-protein supplemented gained 0.59 kg/day (Holderbaum et al, 1991). Total gain for the control steers was 68 kg, whereas total gain for the low-protein and high-protein fed steers was 117 kg and 116.5 kg, respectively.

Nutrient requirements for cattle differ based on sex, production stage, age, and body weight (Paterson and Engle, 2005). It is important to sample forages to estimate nutrient content and to make informed decisions about supplementation.

Salt

As previously discussed, daily salt intake National Academics of Science, Engineering, and Math (2016) is recommended at 11 to 15 grams per day for beef cattle. Salt is present in all organs and fluids of the body (Chapline and Talbot, 1926). When cattle are salt deficient, decreased feed intake and decreased weight gain result (Stewart, 2010). Salt toxicity is possible and will influence the central nervous system and digestive tract of cattle (Sandals, 1978). Toxicity is most likely to occur when cattle have not had salt intake for an extended period of time and then are given free access to salt. Toxicity can also occur when cattle consume salt and do not consume adequate amounts of water or when cattle drink water containing high concentrations of salt (Rich et al., 2004). Cattle can consume approximately 1 g salt/kg of body weight and not display adverse effects; however, consumption above this level may produce toxicity symptoms (Klasing et al*.,* 2005).

Distribution of Cattle Using Salt

Salt placement can affect the grazing distribution of cattle (Chapline and Talbot, 1926) by motivating them to move to areas of pasture that are less grazed. Grazing cattle have the tendency to spend more time near water (Ares, 1953). They will also tend to spend more time grazing palatable plants and less time grazing unpalatable plants (Martin and Ward, 1973). Placing salt exclusively in an infrequently grazed area can attract cattle to that location (Balley and Rittenhouse, 1989).

Martin and Ward (1973) evaluated whether salt alone or cottonseed meal-salt mixes could be used to improve grazing distribution of cattle at the Santa Rita Experimental Range near Tucson, Arizona. Each treatment was used for eight years and included: (1) block salt at water, (2) block salt away from water, (3) block salt at water and meal-salt added from November to

April, and (4) block salt away from water and meal-salt added June to October. The meal-salt mix was a 3:1 ratio of cottonseed meal to salt and was replenished weekly.

Twenty-seven transects were used to determine grazing use of the pasture. The top nine most grazed transects were considered the heavy-use zone, the next nine most grazed transects were considered the medium-use zone, and the nine least grazed transects were the light-use zone. Grazing usage was determined by estimating the utilization of major perennial grass species using the non-grazed plant method (Roach, 1950). Cattle consumed 0.91 kg/head daily when the meal-salt mix was at water; however, when the meal-salt mix was more than a mile away from water, consumption dropped to 0.23 kg/head daily. Plant utilization was 69%, 50%, and 23% in the heavy-, medium-, and light-use zones, respectively, over the 8 years of the experiment. The heavily utilized zone was the closest to the water and the lightly utilized zone was the furthest from the water. Grazing in the light-use zone increased when salt or meal-salt were located far from water (Martin and Ward, 1973).

Supplement Intake Control Using Salt

Salt has been used to control supplement intake (Cardon et al*.,* 1951; Brown et al*.,* 1958). Brown and others (1958) evaluated the use of salt to control the intake of protein supplements. Twenty Hereford heifers were split into two treatments: a control group fed 0.91 kg of cottonseed meal daily and a treatment group which received cottonseed meal with added salt adjusted weekly to regulate intake. By varying the content of salt in the cottonseed meal, they were able to limit the intake of cottonseed meal to 0.91 kg/head daily. The adjustment of salt fed to the treatment group was done weekly.

Protein

Proteins comprise muscle and other organ tissues. Proteins are formed from long chains of amino acids linked together by peptide bonds. Amino acids are composed of an amino group (NH2) and a carboxylic acid group (-COOH) (Lopez and Shamin, 2023). The sequence of the amino acids determines the function of the protein. Protein contains about 16% nitrogen (Lalman and Richards, 2017).

All true protein is comprised of ruminally-degradable protein (RDP; feed protein that can be degraded by microbial enzyme systems in the rumen) and, ruminally-undegradable protein (RUP; bypasses ruminal degradation and is available for degradation and absorption in the small intestine). Metabolizable protein (MCP) is comprised of microbial-cell protein (RDP which has been converted to microbial cell mass) and RUP that reaches the small intestine. Nitrogen from ruminally-degradable protein can either be incorporated directly into microbial cells or absorbed through the rumen wall for transport to the liver. In the liver, ammonia and carbon dioxide are combined to form urea which can be recirculated via the blood stream or saliva to the rumen for protein synthesis (Lalman and Richards, 2017). The protein requirements of cattle are variable based on animal age, body weight, sex, physiological state, and growth rate (Harty and Olson, 2020). Growth performance of grazing cattle is improved with the addition of supplemental protein when forage is below 7% crude protein (Paterson *et al*., 1996).

Non-protein Nitrogen

Crude protein (CP) is a term used to define all true protein and non-protein nitrogen (NPN). Some examples of NPN include urea, biuret, and uric acid. During World War l, NPN was used to supplement nitrogen to the diets of ruminants in Germany. It was not readily available in the United States until 1935 when urea became available in feed manufactures. Since

NPN was a less expensive source of nitrogen at the time, there was an increase in use of NPN in ruminant diets in the United States after World War II (Fonnesbeck et al., 1975).

Urea

Urea (CH_4N_2O) is a common NPN source in ruminant diets that contains about 46% nitrogen (Tadele and Amha, 2015). Urea is dissolved and degraded by bacterial urease and releases ammonia and carbon dioxide. Ammonia, together with volatile fatty acids, is then synthesized into amino acids by ruminal bacteria (Panday, 2011; Nadeem et al., 2014). Amino acids can be used for microbial protein synthesis in the rumen or passed to the lower gut (Helmer and Bartley, 1971).

Brown et al. (1956) fed a lower protein diet (6.7% CP), a urea-supplemented diet (15.1% CP), or a conventional protein diet (15.3% CP) for 84 days to 3 groups of 12 dairy calves. Diets were pelleted and fed *ad libitum* and all calves received medium-quality timothy hay. Milk was fed at 8% of body weight for the first 21 days and then 6, 5, 3, and 2% of body weight the following weeks until day 49. At that time, milk feeding was discontinued. Calves were weighed weekly. At the conclusion of the experiment, urea-supplemented and conventional-protein groups had a greater ADG (0.5 kg and 0.53 kg) compared to the low protein group (0.29 kg). In addition, feed efficiency was greater ($P < 0.01$) for the urea and conventional protein diets compared to the low protein diet. These results demonstrate that urea may be a reasonable nitrogen source when protein levels are low; however, when protein levels are at or near requirements, the addition of supplemental urea has no benefit.

Urea can be a less expensive alternative to natural protein in ruminant diets; however, it is toxic when fed in high concentrations (Tadele and Amha, 2015). Urea content in feed should not exceed 3 percent of the as-fed diet (Tadele and Amha, 2015) The ruminal hydrolysis of urea to ammonia and carbon dioxide is rapid. Ammonia is converted to urea in the liver, normally keeping circulating ammonia low. Ammonia is extremely toxic to non-hepatic tissue and can cause changes in cerebral metabolism resulting in symptoms of toxicity (Symonds et al., 1981). If ammonia is formed faster in the rumen than volatile fatty acids (VFA) created from the fermentation of carbohydrates, ammonia will accumulate and can be absorbed into the bloodstream. If ammonia absorption into the bloodstream exceeds the rate at which the liver can convert ammonia to urea, then ammonia toxicity will occur (Fonnesbeck et al., 1975).

Clark et al. (1951) dosed urea to sheep at a toxic level and documented the symptoms afterwards. They observed dullness, severe muscular twitches, bloating, and muscular tetanic spasms. The animal normally became recumbent, and its legs would stiffen, and labored breathing followed. The regurgitation of ruminal contents frequently occurred, and with death soon after.

Raleigh et al. (1963) determined the optimal degree to which urea could be used to replace natural dietary protein. They individually fed 30 steers a diet containing meadow hay (5.5% CP; DM basis) in all diets and added either urea, cottonseed meal, or both urea and cottonseed meal at crude protein levels of 6, 9, or 12%. On the fifth week of the fifteen-week study, one steer on the 12%-protein diet containing hay and urea alone began to convulse and died. The following week, another steer on the same treatment died. These researchers concluded that urea may cause fatalities when fed in high concentrations.

Biuret

Biuret, a dimer of urea, is not as prone to provoking toxicity as urea. Biuret, which contains 41% nitrogen, is a common NPN source used in ruminant feeding. Biuret is catabolized in the rumen in a similar manner to urea; however, biuretase, as opposed to urease, cleaves biuret into ammonia and CO_2. The ammonia from the breakdown of biuret is combined with volatile fatty acids from enzymatic digestion of carbohydrates to produce amino acids, which then yield microbial cell protein. Microbial cell proteins are subsequently digested in the abomasum and duodenum to peptides and amino acids by mammalian enzymes. Amino acids are absorbed in the small intestine by the animal (Tillman, 2019).

Mackenzie et al*.,* (1964) evaluated supplemental biuret for sheep fed a low-protein, roughage diet. Twenty cross-bred German Merino ewes, were fed 21 g/d or not supplemented (control). Weight loss over the 9-week period was greater for sheep not-supplemented sheep compared to supplemented sheep. Mackenzie et al. (1964) also compared the effects of supplementing biuret or urea to a high-quality hay deit (7.88% CP) or a poor-quality hay diet (4.15% CP) fed to steers. Twenty-four Afrikaner steers and 36 Sussex-Afrikaner steers were assigned to 4 treatment groups. Treatments included steers supplemented with 130.4 g of biuret, 85 g urea, or a control treatment which received neither urea nor biuret. The study was split into two phases. In phase 1, high-quality Teff hay containing 7.88% CP was fed. In phase 2, low-quality Veld grass containing 4.15% CP was fed. In phase 1, the biuret treatment and urea treatment produced similar ADG of 39.2 kg and 39.1 kg, whereas steers assigned to the control group had lesser ADG of 29.9 kg. In phase 2, average daily gains were similar for steers consuming biuret or urea; however, steers assigned to the control treatment lost 20.5 kg during the experiment. These data indicated that supplementation of NPN as biuret or urea when CP levels are low, can increase productivity.

Biuret is potentially, less toxic than urea. Repp et al. (1955) administered various non-protein nitrogen compounds, including urea and biuret, to wether lambs and evaluated blood ammonia levels. The NPN compounds were drenched at nitrogen levels equivalent 15 g of urea per 45.4 kg of body weight and blood samples were collected prior to drenching and 30 minutes post drenching. Doses was increased at increments of 5 g of urea equivalent until half of the lambs showed symptoms of toxicity. Fatal levels were reached when 40 g was dosed; however, when biuret was drenched at 95 g urea equivalent level, no toxic symptoms were displayed. This experiment is in agreement with what Fonnesbeck et al. (1975) who indicated that biuret was hydrolyzed less rapidly than urea.

Safely feeding biuret requires an adaptation period of two weeks to 2 months and it may require up to six months for young calves (Tadele and Amha, 2015). Schröder et al. (1969) investigated the adaptation of ovine ruminal flora to biuret using ruminally fistulated Merino wethers fed forage based diets at different crude protein levels. Biuret was dosed at 15 g with water into the rumen daily. The length of biuret adaptation was associated with the protein content of the diet, with low crude protein diets promoting faster adaptation to biuret than high protein diets. The lowest protein diet reached its peak biuretlytic activity following 13 days of treatment, whereas the high protein diet reached its peak biuretolytic activity in 68 days.

Ruminants can quickly lose any acquired adaptation to biuret if they are not supplemented continuously. Biuretase concentrations decrease rapidly when biuret is not present in the diet (Tadele and Amha, 2015). Clemens et al. (1973) measured biuretolytic activity when biuret was supplemented at varying rates throughout the week. Six ruminally cannulated steers that had previously been adapted to biuret were supplemented biuret directly into the rumen for 32 days. Biuret was supplemented every day, every two days, or every four days. Ruminal fluid samples were collected every two days and on days 5, 9, 13, 17, and 33. On day two, biuretolytic activity was elevated in all treatments; however, on day 4, steers supplemented every four days had less biuretolytic activity compared with steers supplemented every day or every other day.

These researchers also reported that steers supplemented every 4 days had less biuretolytic activity on days 4 through 12 than steers supplemented every day or every other day. Steers supplemented every 4 days still tended to have less biuretolytic activity on days 16, 24, and 32 compared with steers supplemented every day and every other day. These data indicate that biuret may require relatively consistent supplementation to maintain optimum biuretolytic activity.

Ionophores

Ionophores are feed additives that are regulated by the Food and Drug Administration (FDA) (Novilla 2018). Ionophores approved for ruminant feeding include monensin sodium (Rumensin™), laidlomycin propionate (Cattlyst™), and lasalocid sodium (Bovatec™). Ionophores are carboxylic polyether antibiotics produced from a strain of *Streptomyces* bacteria (Marques and Cooke 2021). They are marketed for increased weight gain in cattle, reduced coccidial oocyst release, decreased bloat incidence, and prevention of ruminal acidosis (Novilla 2018). Ionophores act by altering ruminal fermentation resulting in increased propionate production (Novilla 2018), decreased methane production (Johnson and Johnson 1995), and inhibited lactate-producing rumen bacteria (Dennsis et al., 1981).

Mode of Action

Bacterial cellular membranes are selectively permeable to small molecules, allowing them to transit into and out of the cell with no energy expended. Relatively large molecules are unable to pass through the cellular membrane without using pathways such as facilitative diffusion, ion channels, and active transport to mediate transport (Cooper, 2000). Ruminants have relatively high intracellular potassium and low intercellular sodium concentrations, so they rely on ion gradients to absorb nutrients (Chow and Russel, 1992).

Ionophores are lipophilic substance that can act as carriers for metal ions across the lipid-based cellular membrane (Ovchinnikov, 1981;Marques and Cooke, 2021). They can have different effects at the cellular level depending on the structure of the ionophore; however, they all have a similar mode of action (Novilla, 2018). Ion gradients are maintained by Na-K ATPase, which uses the energy from the hydrolysis of ATP to transport Na outside the cell and K inside the cell (Cooper, 2000). This is a form of active transport that requires energy to move against a concentration gradient.

Ionophores alter the ruminal bacterial population by targeting gram-positive bacteria. Ionophores are highly lipophilic (attracted to lipids) and can diffuse across the cellular membranes of bacteria and protozoa (Marques and Cooke, 2021). Gram-negative bacteria have a thin peptidoglycan cell wall that surrounds the bacteria. This layer is surrounded by an outer membrane of lipopolysaccharide. Gram-positive bacteria lack this outer membrane (Silhavy et al. 2010). Without it, they are sensitive to ionophores activity which allows ionophores to enter the bacteria and disrupt normal ion gradients, subsequently inhibiting the bacteria (Marques and Cooke, 2021). One example of this is the ionophore monensin sodium which exchanges either intracellular sodium or potassium with extracellular hydrogen molecules. This decrease in the intracellular pH activated hydrogen ATPase and sodium/potassium systems (Marques and Cooke, 2021; Cooper, 2000).

Ruminal Effects

Investigation of the effects of various compounds on volatile fatty acids (VFA) production in the rumen identified that monensin could increase the proportion of propionate production during ruminal fermentation (Owens, 2021). Monesin was later approved by the FDA for ruminants in 1975. Identification of other ionophores, such as lasalocid, so followed. Lasalocid was approved by the FDA for use in grazing cattle in 1984 (Andersen and Horn, 1987).

Rush et al. (1996) evaluated the effects of Lasalocid and other feed additives on the performance of yearling grazing steers. Lasalocid was supplemented at 200 mg per head daily. Average daily gains were significantly greater for steers supplemented lasalocid (i.e., 0.72 kg/d) compared with non-supplemented calves (i.e., 0.61 kg/d). Furthermore, Spears et al. (1984) observed similar results when supplementing lasalocid to grazing steers. Treatments included control (0 mg lasalocid), 200 mg lasalocid per head daily, or 300 mg lasalocid per head daily. Steers supplemented with lasalocid had improved gains compared with the non-supplemented steers. Weight gains were similar among steers supplemented with 200 or 300 mg of lasalocid daily. In addition, ruminal propionate concentrations were greater in steers supplemented with lasalocid compared with non-supplemented steers.

Andersen and Horn (1987) evaluated the effect of lasalocid on weight gain in heifers grazing winter wheat over two grazing seasons. Heifers were supplemented with either 0, 100, or 200 mg lasalocid per head daily. In year one, heifers supplemented 200 mg lasalocid had greater average daily gain (i.e., 0.9 kg/d) compared with heifers supplemented 100 mg lasalocid (i.e., 0.79 kg/d), and heifers supplemented 0 mg lasalocid (i.e., 0.8 kg/d). Conversely, weight gains in year 2 only tended to increase with increased supplementation of lasalocid.

To determine the effects of lasalocid supplementation on ruminal fermentation characteristics, Anderson and Horn (1987) used eight mature, cannulated Hereford steers supplemented with either no lasalocid daily or 300 mg lasalocid daily. Ruminal fluid samples were collected 4 hours after lasalocid was dosed. Total VFA concentrations did not differ between treatments; however, molar proportions of propionate increased by 1% in the supplemented steers compared to the non-supplemented group. In addition, the acetic-to-propionic acid ratio was less in supplemented steers compared with non-supplemented steers. Isovaleric acid molar proportions also increased by 0.3% in the supplemented steers compared with steers receiving no lasalocid.

Methane

The loss of energy due to methane emission from cattle is about 6% of gross energy intake; it decreases to roughly 3% for cattle fed concentrated diets (Johnson and Johnson, 1995). Ruminal methane production can occur through three different pathways. Those pathways include acetoclastic methanogenesis, methylotrophic methanogenesis, and hydrogenotrophic methanogenesis based on the substrate use for methane production (Fenchel et al., 1998). Most methanogens in the rumen are hydrogenotrophic, in which H_2 is conjugated with CO_2 to form methane (Fenchel et al, 1998). Methanogens themselves are resistant to ionophores; however, ionophores are able to inhibit bacteria that produce hydrogen and formate, which decreases their availability for methane production (Chen and Wolin, 1979).

Gram-positive bacteria that are sensitive to ionophores include bacteria that produce acetic acid, butyric acid, and lactic acid (Marques and Cooke, 2021), resulting in a decrease in the acetate to propionate ratio. The relative proportion of propionate increases because the bacteria that use succinate to produce propionate are resistant to ionophores (Chen and Wolin, 1979). Propionate is the major substrate in ruminants for gluconeogenesis, unlike acetate and butyrate. Ruminant digestion does not produce a significant quantity of glucose, so they rely heavily on gluconeogenesis for their glucose supply (Wiltrout and Satter, 1972). The ratio of acetic to propionic acid influences the ruminal production of methane (Johnson and Johnson, 1995). Fermentation of one molecule of glucose to acetate produces 4 molecules of H^+; however, propionate is a hydrogen sink. When one molecule of glucose is fermented to produce propionate, 2 molecules of H^+ are used (Wang et al*.,* 2023). This use of hydrogen in propionate production improves feed efficiency and animal performance as it decreases the amount of hydrogen available for methane production.

Bartley et al. (1979) evaluated the effects of lasalocid on methane emission *in vitro* with ruminal contents from ruminally fistulated crossbred steers. Steers were fed 5.4 kg of alfalfa hay and 4.5 kg of concentrate and samples were collected before feeding. Lasalocid was added to the ruminal contents at either 0, 22, 44, 88, or 176 ppm of substrate. Proportions of propionate increased with increasing lasalocid up to 88 ppm in the diet. The acetate and propionate ratio decreased up to 88 ppm supplemental lasalocid. Hydrogen, carbon dioxide, and methane gas production were measured after samples were incubated in a water bath. Gas production had a negative quadratic relationship with increasing lasalocid concentration; however, the carbon dioxide to methane ratio increased with increasing lasalocid. This demonstrated that lasalocid may be a useful to decrease methane production in cattle.

When fed to beef cattle, lasalocid improved ADG, increased proportions of propionate, and decreased the acetate to propionate ratio. Lasalocid could also play a role in decreasing intake energy loss due to the release of methane by ruminants.

Conclusion

When forage plants mature, fiber and lignin contents increase, whereas mineral and protein content decreases. The result is reduced forage quality. It is important to analyze forage samples to determine whether they are deficient in protein or minerals. Minerals play an important role in various functions in the body, and it is important to supplement minerals when they are not in adequate quantities to meet the animals' requirements. Protein also plays an important role in animal production. When minerals or protein are deficient cattle performance will decrease.

Many soil factors affect the mineral uptake by forages such as pH, redox potential, texture, organic matter content, mineral composition, temperature, and soil moisture content. When forage mineral content is not adequate, supplementing those minerals may increase the grazing performance of cattle. When dietary protein levels are low, supplementation of NPN, in the form of urea or biuret, to cattle can increase the growth performance of cattle. The inclusion of lasalocid in mineral for grazing cattle can increase ruminal propionate yield and decrease energy loss due to methane production.

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Chapter 2 - Effects of Biuret and Lasalocid (Bovatec) Inclusion into a Commercial Mineral Supplement on Growth Performance of Yearling Calves Grazing in the Kansas Flint Hills

Introduction

In order to optimize growth performance, grazing cattle are usually provided with a mineral supplement. Minerals have many structural, physiological, catalytic, and regulatory roles in the body. Mineral deficiencies can reduce growth performance (Underwood and Suttle, 1999). One strategy to improve growth performance of yearling cattle grazing in the Flint Hills is to add a ruminal modifier or a non-protein nitrogen (NPN) to mineral supplements. As plants mature, fibrous carbohydrates and lignin increase and crude protein decreases (Fonnesbeck et al., 1975). Cattle consuming diets low in protein will have reduced weight gains. Holderbaum et al. (1991) determined that supplementing protein to cattle consuming a low-protein diet had improved average daily gains and overall performance. Non-protein nitrogen (NPN) can substitute for a portion of the natural protein in protein supplements.

Urea and biuret are commonly used NPN sources. Mackenzie et al. (1964) evaluated the effects of supplementing biuret or urea on steers consuming either higher-quality hay (7.9% CP) or poor-quality hay (4.2% CP). Regardless of the quality of hay fed, steers supplemented with biuret or urea had greater ADG compared with steers that were not supplemented. Biuret is less toxic than urea when supplemented to cattle. Repp et al. (1955) determined that, when dosed to sheep, urea reached a fatal toxic dose at 40 g while biuret dosed at an equivalent of 95 g urea nitrogen did not cause toxicity symptoms. There was also no increase in blood ammonia levels unlike sheep dosed with urea. This demonstrates that biuret is hydrolyzed more slowly than urea, resulting in reduced blood ammonia levels (Repp et al., 1955; Fonnesbeck et al., 1975).

Similar to NPN, ionophore supplementation to grazing cattle can improves growth performance and reduces methane production (Bartley, 1979; Andersen and Horn, 1987). Methane is a greenhouse gas. In recent years, greenhouse gas emissions have caused public concern as greenhouse gasses can potentially trap heat in Earth's atmosphere (Segers and Knox, 2022). Methane represents about a 6% of intake energy loss (Johnson and Johnson, 1995). Ionophores are feed additives that alter ruminal fermentation, reduce methane production, and improve cattle performance (Johnson and Johnson, 1995; Novilla, 2018). Lasalocid (Bovatec™) is an ionophore that was introduced in 1984 (Andersen and Horn, 1987). Bartley et al. (1979) demonstrated that supplementing lasalocid to crossbred steers fed 5.4 kg alfalfa and 4.5 kg of concentrate had decreased methane production and increased carbon dioxide to methane ratio. In addition, Andersen and Horn (1987) demonstrated that lasalocid supplementation improved ADG in heifers grazing winter wheat pasture. The addition of a NPN or an ionophore into a mineral supplement could improve growth performance of grazing cattle; therefore, the objective of our experiment was to measure the effects of NPN (i.e., biuret) or NPN + ruminal modifier (i.e., biuret + lasalocid) inclusion in a commercial mineral mix on the growth performance of yearling beef calves grazing in the Kansas Flint Hills over a 2-year period.

Materials and Methods

All procedures involving the use of animals were approved by Kansas State University Institutional Animal Care and Use Committee (IACUC #4182.13). The experiment was conducted at the Kansas State Beef Stocker Unit during the 2021 and 2022 grazing seasons.

Over a 2-year period, 742 crossbred steers (initial body weight: 297 ± 23.7 kg) previously backgrounded at the Kansas State Beef Stocker Unit were used in our experiment. Steers were blocked by previous experiment treatment and randomly assigned to 1 of 18 pastures to achieve a stocking density of 280 kg live weight per hectare. Pastures ranged in size from 12 to 30 ha. Pastures were enrolled in a long-term prescribed-fire timing experiment previously described by (Duncan et al., 2021). In that experiment, pastures were assigned to one of three prescribed fire treatments: spring, summer, or fall. Each burn treatment contained 6 pastures; therefor, to balance for any carry-over effects in our experiment, our treatments were randomly assigned to pasture within prescribed-fire treatment so that each was represented twice. Due to unfavorable burn conditions, burn treatments were not applied in year 2.

Mineral treatments included a basal supplement (control), basal supplement with biuret (biuret; 17 g/head daily), basal supplement with biuret (17 g/head daily) plus lasalocid (lasalocid; 80 mg/head daily). Biuret was included in the mineral supplement at 150 g/kg (DM basis) and lasalocid was included in the supplement at 7.75 g/kg (DM basis; Table 2.1). Mineral was delivered weekly and fed to target consumption of 113.4 g per head daily. Identical supplement feeders (Bullmaster; Mann Enterprises, Inc., Waterville, KS) were used in each pasture.

Prior to grazing, steers were given individual identification tags, treated for external (Standguard®; Elanco, Greenfield, IN) parasites, and internal (Valbazen®; Zoetis Animal Health, Parsippany-Troy Hills, NJ) parasites, administered a growth-promoting implant (Ralgro®; Zoetis Animal Health, Parsippany-Troy Hills, NJ), and weighed individually using a hydraulic squeeze chute (Silencer, Moly Manufacturing Inc., Lorraine KS). The day grazing began, steers were sorted into pasture groups and weighed using a pen scale (Rice Lake Weighing System, Rice Lake, WI) to determine average initial body weights per pasture. Steers were turned out over a 3-day period based on prescribed-fire treatment. Calves assigned to summer prescribed-fire treatment were turned out on May 4^{th}, calves assigned to the fall prescribed-fire treatment on May 5^{th}, and calves assigned to the spring prescribed-fire on May 6^{th}. Steers grazed for 90 days and were gathered on their respective day based on what prescribed fire treatment they were assigned to (i.e., summer August 2, fall August 3, and spring August 4). Steers were gathered and immediately weighed using a pen scale to determine average final body weights.

Mineral feeders were initially placed uncovered near water tanks to allow cattle to locate the mineral supplement for approximately 2 weeks. Following the 2-week adaptation period, flaps were lowered for the remainder of the grazing season. In the event of anticipated inclement weather, mineral feeders were covered to prevent rain from entering mineral feeders. If calves were consistently consuming their weekly mineral allotment, feeders were moved away from water for the remainder of the grazing season. Mineral feeders were weighed weekly to estimate mineral consumption. After weighing feeders, they were refilled with their respective mineral treatments to target a consumption of 113.4 g per head daily. In addition, mineral feeders were observed daily to monitor cleanliness and mineral consumption. When the feeders were empty, the date was recorded and was used to estimate rate of mineral consumption (i.e., days-to-empty).

To estimate forage quality, samples were collected monthly in year 1 (i.e., May 14, June 6, July 2, and August 2) and year 2 (i.e., May 16, June 2, July 5, and July 27). A 100-m transect was established in each pasture. Two pastures from each prescribed-fire treatment were randomly selected to estimate forage quality (n = 6 pastures). Forage samples were collected using two 50 x 50-cm clipping frames placed randomly alongside each transect. The square was tossed, and the enclosed forage was clipped 3 cm above the soil in each pasture. Samples were immediately frozen until the completion of the experiment. At the end of the grazing season, all samples were sent to a commercial laboratory for nutrient analysis (SDK Laboratories, Hutchinson, KS). Samples were analyzed for dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (aNDF). Samples were also analyzed for mineral concentrations of calcium, phosphorus, potassium, magnesium, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc. In addition, samples of mineral supplements were collected in year in year 1 at the initial filling of the bags at the site of manufacture (Key Feeds, Clay Center, KS). A representative sample was collected from each mineral treatment and sent to a commercial laboratory (SDK Laboratories, Hutchinson, KS). In year 2, mineral samples were collected every 4 weeks (i.e., June 3, July 1, and July 27) directly from mineral bag. At the conclusion of the experiment, mineral samples were composited and sent to a commercial laboratory for mineral analysis (SDK Laboratories, Hutchinson, KS). In both years, samples were collected to determine calcium, phosphorus, potassium, magnesium, sodium, sulfur, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc concentrations.

Statistical Analysis

Performance data, mineral consumption, and days-till-empty were analyzed as using a mixed-model (PROC MIXED; SAS 9.4, SAS Inst. Inc, Cary, NC). Data were analyzed for year 1, year 2, and years 1 and 2 combined. When performance data were analyzed by year, class variables included pasture, mineral treatment, and prescribed-fire treatment. The model included mineral treatment, prescribed-fire treatment, and mineral treatment × prescribed-fire treatment as fixed effects. For mineral consumption and days-till-empty for individual years, class variables included mineral treatment, prescribed-fire treatment, and week. The model contained fixed effects for mineral treatment, prescribed-fire treatment, week, and all possible interactions.

When performance data for both years was combined, class variables included mineral treatment, prescribed-fire treatment, pasture, and year. The model contained fixed effects for mineral treatment, prescribed-fire treatment, year, and all interactions. When mineral consumption and days-till-empty were combined, class variables included mineral treatment and prescribed-fire treatment as fixed effects and week as the repeated measure. Significance was declared at $P \leq 0.05$ and tendencies at $0.05 \leq P \leq 0.01$.

Results and Discussion

Overall total body weights gains, average daily gains, and mineral consumption did not differ among mineral treatments ($P \leq 0.15$; Table 2.2). Final body weights were greater ($P \leq 0.03$) for biuret and biuret + lasalocid compared with control. Supplementation of NPN may have increased performance as reported by Mackenzie et al. (1964).

Total body weight gains, average daily gains, and mineral consumption did not differ among prescribed-fire treatments ($P \leq 0.47$; Table 2.3); however, final body weights tended to be greater ($P \leq 0.06$) for spring- and summer-burned pastures compared with fall-burned pastures. Forage quality differed between years. Dry matter percentage was greater in year 2 while crude protein was greater in year 1 (Table 2.4, Table 2.5). These differences occurred because in year 1, pastures received prescribed-fire treatments; however, in year 2 prescribed-fire treatments were not applied due to unsuitable weather conditions. Ehrenreich (1959) evaluated the effects of prescribed-fire on the growth habits of Iowa prairie grass. Burned areas had earlier growth compared to non-burned areas. This earlier growth may increase forage quality (Fonnesbeck et al., 1975). The improved forage quality in year 1 may have improved overall cattle growth performance.

Mineral consumption was lesser (week: $P \leq 0.01$) during weeks 1 to 3 compared with the remainder of the grazing season in both years. The number of days required for calves to consume their weekly allotment was below targeted consumption; however, after calves acclimate to their pastures and located their mineral feeders, the rate of mineral consumption began to increase. Neophobia occurs when animals are introduced to novel feedstuff and could have contributed to low, initial mineral intakes (Forbes, 1996).

Days-to-empty was greater (week: $P \leq 0.01$) in week 7 compared to remainder of the grazing season. The increase in days-to-empty was coincident with an increase in ambient temperature during both years 1 and 2 during week 7 (National Weather Service, 2023; Figure 2.1 and figure 2.2). In year 1, days-to-empty increased from weeks 5 to 7. Prior to the increase in days-to-empty in year 1, week 4 ambient temperatures averaged 21.1 C°. By the end of week 5, ambient temperature increased to an average of 29.9 C°. Calves acclimated to the increase in ambient temperatures and shortly mineral treatments returned to between 2 and 4 days-to-empty at each observation by week 8. In year 2, days-to-empty increased in week 7 coincident with increased ambient temperatures. During week 7 of the experiment, temperatures reached 37.8 C°, a high for the month of June, with an average of 34.3 C° for week 7. The long-term average high for June; however, was 29.9 C°. Once calves adapted to the increase in ambient temperatures, days-to-empty returned to an average of 2 to 3 days for the remainder of the grazing season in year 2. Hill and Wall (2017) observed that as temperature-humidity index (THI) increased, feed intake of cows decreased. Animals that experience heat stress reduce feed intake, which is assumed to occur because fermentation generates heat (Baumgard and Rhoads, 2012).

Days-to-empty was greater (mineral treatment ×week: $P \leq 0.03$; Figure 2.3) during weeks 2 and 3 for biuret and biuret + lasalocid compared with control. In addition, days-to-empty for weeks 4, 5, 6, and 7 was greater ($P = 0.02$) for biuret + lasalocid compared with control. In week 5, days-to-empty was greater ($P \leq 0.01$) for biuret + lasalocid compared with biuret. Days-to-empty tended to be greater ($P = 0.09$) for biuret compared with control in week 6 and 7. At the initiation of the experiment, biuret and biuret + lasalocid minerals were consumed at a slower rate compared to control; however, these differences disappeared after week 5 for biuret and after week 8 for biuret + lasalocid. We concluded that the control mineral was consumed more rapidly than other treatments because it may have taken more time for calves to adapt to consuming biuret and biuret + lasalocid.

Days-to-empty also differed among prescribed-fire treatments (prescribed-fire treatment × week: $P \leq 0.04$; Figure 2.4) among weeks. Days-to-empty in week 2 were greater ($P = 0.03$) in spring-burned pastures compared with summer-burned pastures. In week 5, days-to-empty were greater ($P = 0.02$) in fall-burned and spring-burned pastures compared with summer-burned pastures. Days-to-empty were greater ($P = 0.04$) in fall-burned pastures compared with summer-burned pastures in week 7; however, in weeks 12 and 13 days-to-empty were greater ($P = 0.04$) in spring-burned pastures compared with fall-burned pastures and tended to be greater ($P = 0.06$) in week 13 in spring-burned pastures compared with summer-burned pastures.

Overall, spring-burned pastures tended to have greater ($P = 0.09$) average days-to-empty compared with fall- and summer-burned pastures. This could be due to the carry over effect from year 1 prescribed fire treatment, as year 2 did not receive the application of fire. Prescribed-fire treatments were not applied in year 2 due to unsuitable weather conditions. Overall forage quality is greatly affected by plant maturity and as forage matures, forage mineral content decreases (Oelberg, 1956) and plant palatability decreases (McDowell, 1996). As a result, cattle consuming mature forages consume fewer plant-sourced minerals than cattle consuming less mature forage (Fonnesbeck et al., 1975). As a result, mineral supplement intake increases with increased plant maturity. The spring-prescribed fire treatment was applied on April 15, 2021, three weeks prior to calves being turned out to pasture. This would allow for the forage on the spring-prescribed pastures to be marginally less mature than the summer- and fall-prescribed fire treatments, which were burned on August 25, 2020, and September 22, 2020. Spring-burned pastures had less dry matter on June 6^{th} and July 2^{nd} than other fire treatments. Crude protein in spring-burned pastures was also greater on May 14^{th}, June 4^{th}, and July 2^{nd} compared to summer-burned pastures (Table 2.4). This indicated that spring-burned pastures were less mature on those dates. Decreased forage maturity may have stimulated intake of forage and decreased intake of supplemented mineral intake, which is why days-to-empty may be less compared to summer and fall prescribed fire treatments.

In year 1, mineral concentrations also varied between prescribed-fire treatments (Table 2.6). Phosphorus concentrations were greater in spring-burned pastures after June 4^{th}. Potassium and magnesium levels were greater in spring-burned pastures on June 4^{th} but were similar to other burned pastures on later sampling dates. Aluminum was greater on May 15^{th} while it decreased on June 4^{th} and then increased to become greater in spring-burned pastures on July 2^{nd} and August 2^{nd} compared with fall- and summer-burned pastures. On June 4^{th}, summer-burned pastures had lesser copper compared to spring- and fall-burned pastures; however, these differences disappeared on July 2^{nd} and returned to similar values as spring- and fall-burned pastures thereafter. Iron values were lesser in summer-burned pastures following June 4^{th} sampling compared to spring- and fall-burned pastures. Spring-burned pastures had greater manganese values on June 4th however were similar to fall- and summer-burned pastures the remainder of the grazing season. Cobalt, molybdenum, and zinc values were all similar between burn treatments during the grazing season (Table 2.6). However, forage quality was similar between prescribed-fire treatments during year 2 (Table 2.5) and mineral concentrations were also similar among prescribed-fire treatments in year 2 (Table 2.7) due to year 2 not having fire applied prior to the start of the grazing season.

Implications

At the conclusion of years 1 and 2, our data was interpreted to suggest that the addition of biuret or biuret + lasalocid to commercial mineral supplement improved the growth performance of yearling beef cattle grazing in the Kansas Flint Hills. The use of prescribed fire was associated with gross improvement to overall forage quality. When forage quality is high, supplementing mineral may not increase cattle performance. Cattle will have decrease supplement consumption at the initiation of supplementation as they may be experiencing neophobia. Cattle will also have decreased supplement consumption with increased ambient temperatures. These factors will all have an effect on whether or not cattle will have increased performance with the inclusion of ruminal modifiers or non-protein nitrogen (NPN) in mineral supplements.

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Tables

Table 2.1. Mineral ingredients and nutrient composition[1]

	Mineral Treatment		
Item	**Control**	**Biuret**	**Biuret + Lasalocid**
Ingredient, %			
Biuret	-	15	15
Sulfur Flour	-	0.2	0.2
Lasalocid	-	-	0.8
Salt	24.3	24.3	24.3
Monocalcium Phosphate 21%	19.3	19.3	19.3
Calcium Carbonate	17.5	15	15
Dried Distillers	15.5	15.5	15.5
Magnesium-mica	10	0.79	-
Dried Molasses	6	6	6
Soy Hulls	4.25	-	-
Soy Oil	1	1	1
Magnesium Oxide	0.75	1.5	1.5
Zinc Oxide	0.75	0.75	0.75
Copper Sulfate	0.4	0.4	0.4
Vit A 60,000/GM	0.3	0.3	0.3
EDDI	0.05	0.05	0.05
Calculated Nutrient Composition			
Dry matter, %	96.46	97.14	97.14
Crude Protein, %	5.4	42.9	42.9
Crude Fat, %	2.27	2.18	2.18
Crude Protein, NPN, %	-	37.95	37.95
TDN, %	21.03	18.05	18.05
Calcium, %	10.35	9.28	9.27
Phosphorus total, %	4.24	4.2	4.2
Salt, %	24.23	24.23	24.23
Sodium, %	9.71	9.66	9.66
Chloride, %	14.74	14.74	14.74
Potassium, %	0.66	0.43	0.41
Magnesium, %	1.38	1.06	1
Sulfur, %	0.33	0.542	0.542
Manganese, PPM	197.8	137.9	132.8
Zinc, PPM	5485.6	5439.6	5435.6
Iron, PPM	1061.2	1024.3	1021.2
Copper, PPM	1019.3	1013.7	1013.3
Cobalt, PPM	52	5.93	2
Iodine, PPM	495.1	495.1	495.1
Selenium, PPM	0.056	0.056	0.056
Vitamin A, total KIU/lb	81.65	81.65	81.65
Bovatec mg/lb	-	-	705.3

[1]Formulated for 4 oz of mineral consumption per day. Dr. Frank Brazle, 2021, personal communication

Table 2.2. Effects of biuret with or without lasalocid on yearling stocker cattle growth performance in the Kansas Flint Hills, year 1 & year 2

	Mineral Treatments				
Item	Control	Biuret	Biuret + Lasalocid	SEM*	*P*-value†
Initial bodyweight, kg	296	296	299	2.8	0.66
Final bodyweight, kg	370[b]	375[a]	378[a]	2.0	0.03
Total bodyweight gain, kg§	74	79	79	2.2	0.15
Average daily gain, kg/day∔	0.82	0.88	0.88	0.02	0.15
Mineral consumption, oz/head/day	3.90	3.86	3.85	0.05	0.79

*Mixed- model standard error of the mean (SEM) associated with comparison of treatment main-effect means.

†Treatment main effect

§Calculated as final body weight – initial body weight

∔Calculated as body weight gain ÷ total grazing days (90 d)

[a, b] Within rows, means with unlike superscripts differ ($P \leq 0.05$)

Table 2.3. Effects of prescribed fire on yearling stocker cattle growth performance in the Kansas Flint Hills, year 1 & year 2

	Prescribed Fire Treatment				
Item	Fall	Spring	Summer	SEM*	*P*-value†
Initial bodyweight, kg	295	297	300	2.8	0.54
Final bodyweight, kg	370[b]	376[a]	378[a]	2.0	0.06
Total bodyweight gain, kg§	75	79	78	2.2	0.50
Average daily gain, kg/day∻	0.84	0.88	0.87	0.02	0.50
Mineral consumption, oz/head/day	3.86	3.83	3.93	0.05	0.47

*Mixed- model standard error of the mean (SEM) associated with comparison of treatment main-effect means.
†Treatment main effect
§Calculated as final body weight – initial body weight
∻Calculated as body weight gain ÷ total grazing days (90 d)
a, b Within rows, means with unlike superscripts differ ($P \leq 0.05$)

Table 2.4. Forage composition of prescribed fire treatments, year 1

Item	Prescribed Fire Treatment		
	Fall	Spring	Summer
Dry matter, %			
5/18/21	32.76	33.88	32.05
6/4/21	35.98	28.39	40.88
7/2/21	45.49	40.16	46.77
8/2/21	43.03	45.41	44.45
Crude protein, % DM			
5/18/21	12.33	14.61	12.34
6/4/21	12.28	11.32	7.8
7/2/21	7.87	7.37	5.82
8/2/21	6.27	5.61	6.22
Acid detergent fiber, % DM			
5/18/21	29.88	29.96	28.31
6/4/21	33.40	29.04	31.37
7/2/21	35.72	32.68	33.70
8/2/21	32.94	34.57	35.27
Neutral detergent fiber, % DM			
5/18/21	50.95	56.42	46.91
6/4/21	50.76	50.76	58.61
7/2/21	63.24	63.24	59.89
8/2/21	62.94	62.94	60.67

Two pastures within each prescribed fire treatment were measured. Each pasture was sampled twice and composited within each sampling date. Samples were sent to SDK Labs, Hutchison, KS to be analyzed for dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (aNDF).

Table 2.5. Forage composition of prescribed fire treatments, year 2

	Prescribed Fire Treatment		
Item	Fall	Spring	Summer
Dry matter, %			
5/16/22	55.34	59.01	54.39
6/2/22	47.58	48.55	46.84
7/5/22	44.63	49.58	46.96
7/29/22	51.10	55.01	51.34
Crude protein, %, DM			
5/16/22	6.92	5.70	5.06
6/2/22	6.35	6.33	6.11
7/5/22	5.56	4.81	4.96
7/29/22	4.95	4.40	4.89
Acid detergent fiber, % DM			
5/16/22	38.46	37.55	39.21
6/2/22	37.20	36.11	36.52
7/5/22	36.46	36.91	36.87
7/29/22	39.04	37.15	37.73
Neutral detergent fiber,% DM			
5/16/22	63.72	64.24	63.94
6/2/22	63.76	63.91	63.50
7/5/22	63.17	65.39	64.25
7/29/22	66.11	68.15	64.80

Each prescribed fire treatment was replicated twice so a total of 9 pastures were collected. Each pasture was sampled twice and composited within each sampling date. Samples were sent to SDK Labs, Hutchison, KS to be analyzed for dry matter (DM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (aNDF).

Table 2.6. Effects of prescribed-fire timing on mineral content, year 1

	Prescribed Fire Treatment[1]		
Item	Fall	Spring	Summer
Calcium, %			
5/14/21	0.68	0.56	0.85
6/4/21	0.71	1.08	0.54
7/2/21	0.70	0.71	0.67
8/2/21	0.89	0.51	0.86
Phosphorus, %			
5/14/21	0.14	0.21	0.12
6/4/21	0.14	0.19	0.11
7/2/21	0.06	0.11	0.05
8/2/21	0.06	0.11	0.06
Potassium, %			
5/14/21	1.59	1.53	1.39
6/4/21	1.37	1.95	1.31
7/2/21	1.22	1.18	1.08
8/2/21	1.11	1.05	1.15
Magnesium, %			
5/14/21	0.17	0.20	0.19
6/4/21	0.16	0.24	0.15
7/2/21	0.16	0.17	0.12
8/2/21	0.19	0.17	0.18
Aluminum, ppm			
5/14/21	345	498	395
6/4/21	538	381	514
7/2/21	612	645	635
8/2/21	507	715	487
Cobalt, ppm			
5/14/21	0.56	0.62	0.2
6/4/21	Less than 0.2	Less than 0.2	0.2
7/2/21	Less than 0.2	Less than 0.2	Less than 0.2
8/2/21	Less than 0.2	Less than 0.2	Less than 0.2
Copper, ppm			
5/14/21	10.90	13.93	14.42
6/4/21	22.50	24.65	4.33
7/2/21	6.68	5.22	7.50
8/2/21	7.08	6.44	7.67
Iron, ppm			
5/14/21	494	360	436
6/4/21	340	397	281
7/2/21	377	314	276
8/2/21	312	429	248
Manganese			
5/14/21	58.70	65.05	66.60
6/4/21	42.90	59.25	52.25

Table 2.6. continued			
7/2/21	43.50	49.55	46.15
8/2/21	43.75	55.10	36.93
Molybdenum, ppm			
5/14/21	0.80	1.18	0.55
6/4/21	1.20	1.04	1.18
7/2/21	1.28	1.11	2.00
8/2/21	1.90	2.45	2.05
Zinc, ppm			
5/14/21	33.28	30.55	31.20
6/4/21	34.8	36.15	21.55
7/2/21	29.73	26.95	26.18
8/2/21	37.10	29.35	29.50

Samples were sent to SDK Labs, Hutchison, KS to be analyzed for calcium, phosphorus, potassium, magnesium, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc

Table 2.7. Effects of prescribed-fire timing on mineral content, year 2

	Prescribed Fire Treatment[1]		
Item	Fall	Spring	Summer
Calcium, %			
5/16/22	0.67	0.54	0.61
6/2/22	0.52	0.57	0.54
7/5/22	0.59	0.57	0.52
7/29/22	0.57	0.52	0.61
Phosphorus, %			
5/16/22	0.12	0.10	0.12
6/2/22	0.13	0.13	0.15
7/5/22	0.12	0.11	0.13
7/29/22	0.09	0.14	0.10
Potassium, %			
5/16/22	1.22	0.55	0.82
6/2/22	0.92	0.92	0.94
7/5/22	1.02	0.84	0.91
7/29/22	0.82	0.70	0.91
Magnesium, %			
5/16/22	0.08	0.08	0.09
6/2/22	0.10	0.10	0.09
7/5/22	0.12	0.11	0.11
7/29/22	0.12	0.10	0.11
Aluminum, ppm			
5/16/22	705	768	662
6/2/22	516	557	605
7/5/22	427	615	526
7/29/22	503	619	506
Cobalt, ppm			
5/16/22	0.2	0.38	0.2
6/2/22	0.2	Less than 0.2	Less than 0.2
7/5/22	Less than 0.2	0.33	0.2
7/29/22	Less than 0.2	Less than 0.2	0.2
Copper, ppm			
5/16/22	5.05	4.35	4.76
6/2/22	4.95	4.21	4.90
7/5/22	6.62	5.46	4.42
7/29/22	4.68	3.74	5.36
Iron, ppm			
5/16/22	650	559	447
6/2/22	399	391	427
7/5/22	271	372	323
7/29/22	295	359	285
Manganese			
5/16/22	44.35	42.30	45.20
6/2/22	37.4	34.50	46.40

Table 2.7. continued			
7/5/22	29.70	34.83	38.07
7/29/22	35.5	33.97	39.17
Molybdenum, ppm			
5/16/22	1.19	1.49	1.27
6/2/22	1.22	1.17	1.32
7/5/22	1.24	1.72	1.14
7/29/22	1.53	1.37	1.22
Zinc, ppm			
5/16/22	32.90	28.97	32.63
6/2/22	27.07	25.93	28.40
7/5/22	24.87	29.23	27.27
7/29/22	26.23	23.57	37.23

Samples were sent to SDK Labs, Hutchison, KS to be analyzed for calcium, phosphorus, potassium, magnesium, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc

Table 2.8. Composition and nutrient analysis of mineral treatments, year 1

	Mineral Treatment		
Item	Control	Biuret	Biuret + Lasalocid
Calcium, %	10.50	7.11	9.61
Phosphorus, %	4.09	4.63	5.25
Potassium, %	0.65	0.68	0.52
Magnesium, %	3.52	1.04	1.27
Sodium, %	8.05	8.13	8.57
Sulfur, %	0.55	0.62	0.70
Aluminum, ppm	149	79.7	112
Cobalt, ppm	2.28	<0.2	0.2
Copper, ppm	909	427	1010
Iron, ppm	3400	1280	1600
Maganese, ppm	290	68.2	106
Molybdenum, ppm	4.01	2.46	4.03
Zinc, ppm	4640	3130	5550

Mineral treatments were sampled directly from Key Feeds, Clay Center, KS when mineral bags were being filled. Samples were sent to SDK Labs, Hutchison, KS to determine mineral composition. Mineral treatments analyzed for calcium, phosphorus, potassium, magnesium, sodium, sulfur, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc. Parts per million (PPM).

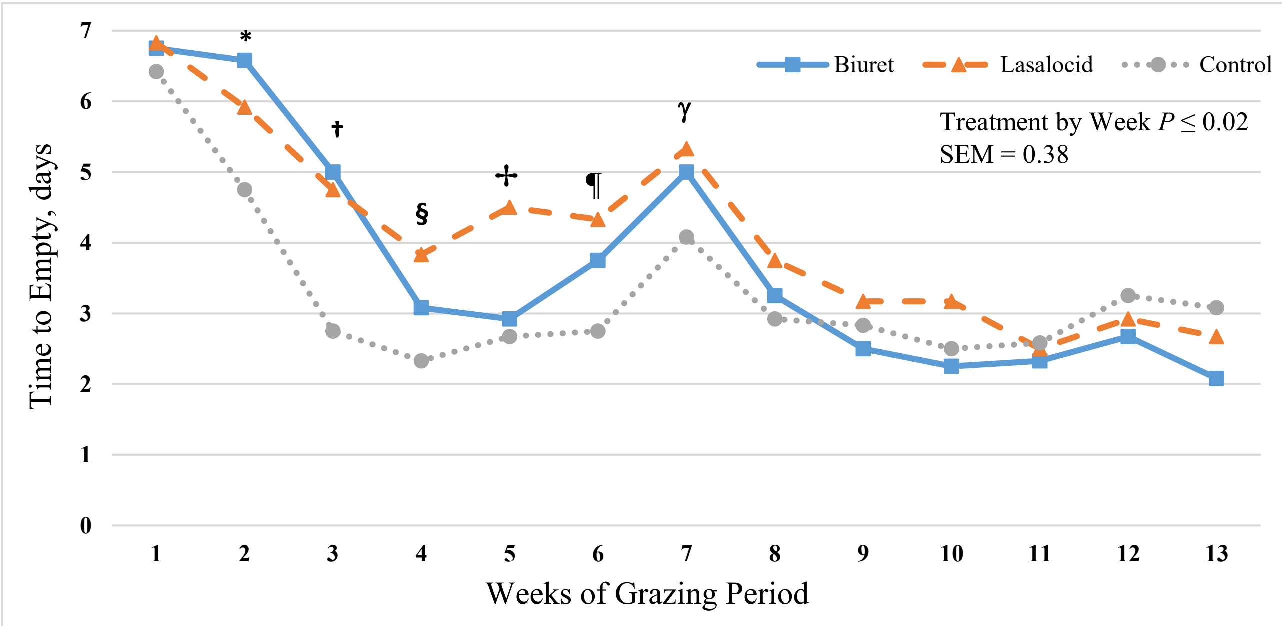
Table 2.9. Composition and nutrient analysis of mineral treatments, year 2

	Mineral Treatment		
Item	Control	Biuret	Biuret + Lasalocid
Calcium, %	8.60	7.82	10.10
Phosphorus, %	3.50	3.39	4.12
Potassium, %	0.87	0.66	0.63
Magnesium, %	1.28	0.91	0.97
Sodium, %	7.27	8.27	6.56
Sulfur, %	0.16	0.18	0.22
Aluminum, ppm	2560	1270	1220
Cobalt, ppm	6.03	2.78	2.11
Copper, ppm	942	1150	1490
Iron, ppm	5560	2040	1990
Maganese, ppm	771	233	197
Molybdenum, ppm	3.60	2.55	3.24
Zinc, ppm	5760	6280	7980

Mineral treatments were sampled every 4 weeks (i.e. June 3, July 1, July 27) and composited. Composited samples were sent to SDK Labs, Hutchison, KS to determine mineral composition. Mineral treatments analyzed for calcium, phosphorus, potassium, magnesium, sodium, sulfur, aluminum, cobalt, copper, iron, manganese, molybdenum, and zinc. Parts per million (PPM).

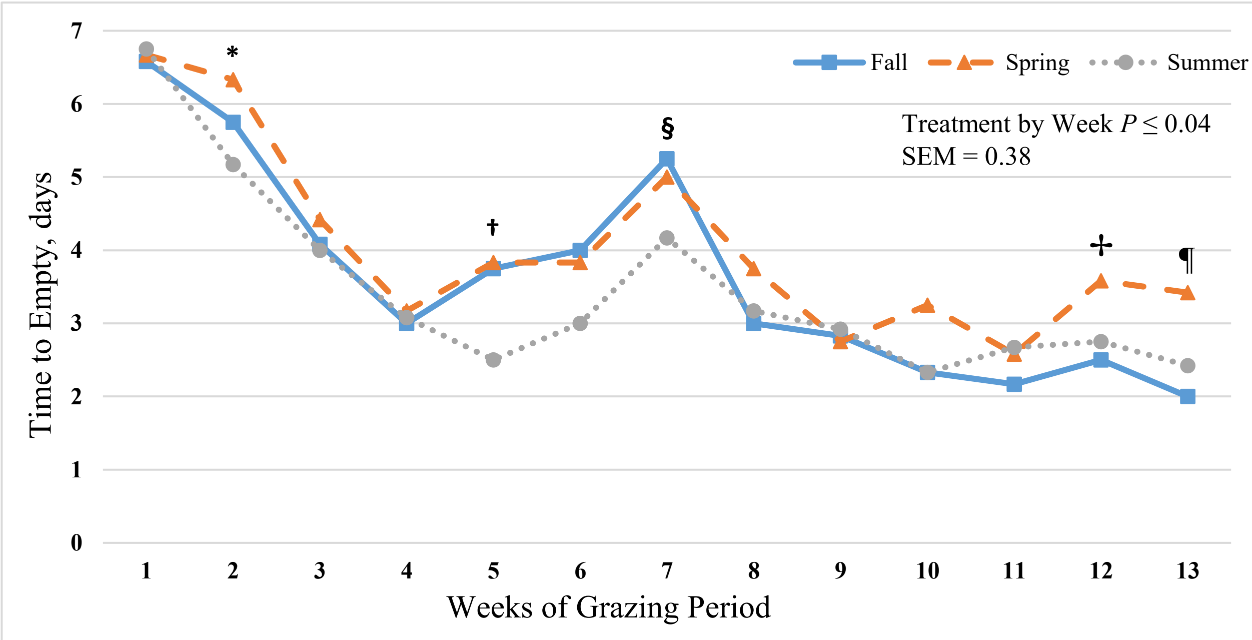
Figures

Figure 2.1. Effects of Biuret with or without lasalocid on weekly mineral consumption rate of yearling cattle grazing Kansas Flint Hills, Year 1 and Year 2. Days-to-Empty collected daily for each pasture and averaged between treatments.



*Week 2 Biuret > Control ($P < 0.01$), Lasalocid > Control ($P < 0.03$), Biuret = Lasalocid ($P = 0.21$)
†Week 3 Biuret > Control ($P < 0.01$), Lasalocid > Control ($P < 0.01$), Biuret = Lasalocid ($P = 0.64$)
§Week 4 Lasalocid > Control ($P < 0.01$), Biuret = Control ($P = 0.16$), Biuret = Lasalocid ($P = 0.16$)
⁺Week 5 Lasalocid > Control ($P < 0.01$), Lasalocid > Biuret ($P < 0.01$), Biuret = Control ($P = 0.64$)
¶Week 6 Lasalocid > Control ($P < 0.01$), Biuret= Control ($P = 0.06$), Biuret = Lasalocid ($P = 0.27$)
γWeek 7 Lasalocid > Control ($P = 0.02$), Biuret = Control ($P = 0.09$), Biuret = Lasalocid ($P = 0.53$)

Figure 2.2. Effects of prescribed fire treatment on weekly mineral consumption rate of yearling cattle grazing Kansas Flint Hills, Year 1 and Year 2. Days-to-Empty collected daily for each pasture and averaged between treatments.



*Week 2 Spring > Summer (P = 0.03), Spring = Fall (P = 0.27), Fall = Summer (P =0.27)
†Week 5 Fall > Summer (P = 0.02), Spring > Summer (P = 0.01), Fall = Spring (P =0.88)
§Week 7 Fall > Summer (P = 0.04), Spring = Summer (P = 0.12), Fall = Spring (P = 0.64)
+Week 12 Spring > Fall (P = 0.04), Spring = Summer (P = 0.12), Fall = Summer (P = 0.64)
¶Week 13 Spring > Fall (P < 0.01), Spring = Summer (P = 0.06), Fall = Summer (P = 0.43)

Figure 2.3. Daily maximum, minimum, and average temperature (°C), Year 1. Obtained from historical records from National Weather Service (http://www.weather.gov) for year 2021. Weather station located within 40 miles of Manhattan, KS.

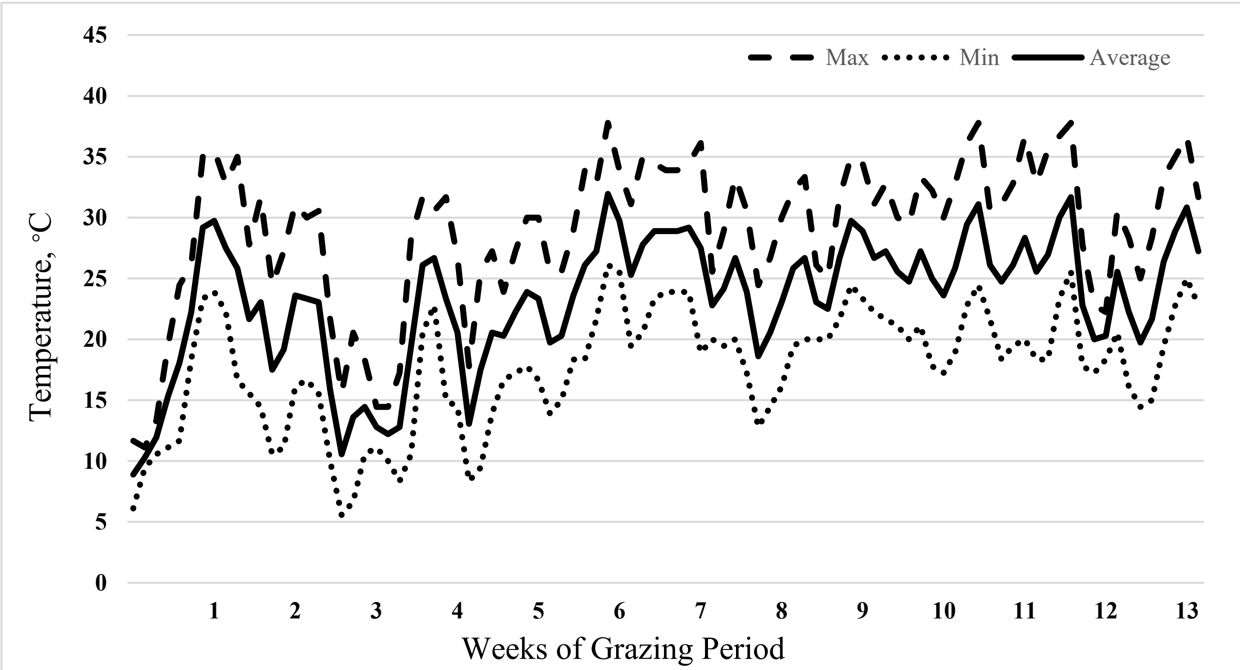


Figure 2.4. Daily maximum, minimum, and average temperature (°C), Year 2. Obtained from historical records from National Weather Service (http://www.weather.gov) for year 2022. Weather station located within 40 miles of Manhattan, KS.