SUPPLEMENT INTAKE BEHAVIOR OF HEIFERS GRAZING LATE SUMMER DRYLAND PASTURE

by

Tyrell Phillip McClain

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DEDICATION

To my wife and children.

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I am grateful for the opportunity I have had to participate in an amazing program in the pursuit of a master's degree. From the time I was in 7th grade I knew I wanted to be a ruminant nutritionist. I would like to extend my sincere gratitude to Dr. Tim DelCurto who has pushed and helped guide me through my journey at Montana State. His sincere desire to help others and his ever-extending encouragement to keep going has been a true motivation to me through this journey. He has been extremely patient with me, and my non-traditional option of graduate school, making it possible wherever I have been to have the resources to accomplish this great task. I would also like to thank Dr. Sam Wyffels for his friendship, patience, and guidance. You were always there to help lift and encourage me along the journey.

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ABSTRACT

Two studies were conducted to evaluate supplement intake and intake behavior of Rumax BoviBox protein supplements. For both studies, individual supplement intake, time spent at the feeder, and frequency of visits was measured using a SmartFeed Pro self-feeder system. In study 1, we examined the effects of free choice loose mineral salt on protein block supplement intake behavior of first-calf heifers. Heifers were stratified by weight, and, within stratum, randomly allotted to one of two supplementation treatments: 1) free-choice access to protein block supplement (30% CP) with access to loose mineral and salt; and 2) free-choice access to protein block supplement (30% CP) with no access to loose mineral and salt for a 42-day performance study. Individual animal was considered the experimental unit. No differences were observed for total supplement intake or supplement intake expressed as grams per kg body weight (BW; $P > 0.05$). In summary, availability of loose mineral salt did not have an impact on protein block supplement intake. In study 2, we evaluated Rumax BoviBox versus Rumax BoviBox HM protein supplements on supplement intake, intake behavior, body weight (BW), and body condition score (BCS) change of yearling heifers grazing dryland pastures during late summer. Heifers (428 kg) were stratified by BW and within stratum randomly assigned to one of two supplementation treatments: 1) free-choice access to Rumax BoviBox protein block supplement (30% CP, 23% salt; n = 29); and 2) free-choice access to Rumax BoviBox HM high magnesium protein block supplement (28.7% CP, 23% salt; n = 30). Supplement intake rate (g · min-1) displayed a treatment effect ($P < 0.01$) indicating that heifers in the Rumax BoviBox treatment had lower intake rate compared to Rumax BoviBox HM supplemented heifers. In conclusion, there were only minor differences in intake behavior and animal performance observed in both trials.

CHAPTER ONE

GENERAL INTRODUCTION

Beef production is an important facet to the global economy and is the top agricultural commodity in Montana. In 2019, there were 380,000 replacement heifers developed in Montana, representing 15% of all cattle in the state (NASS, 2019). Proper heifer development needs to be economically managed without sacrificing heifer performance (Funston and Deutscher, 2004). Heifers developed in forage-based systems may provide economic advantages compared to heifers developed on high quality diets in confinement (Funston et al., 2007; Mulliniks et al., 2012).

Producers' ability to develop heifers in an economically fiscal manner has been limited by the high cost and lack of labor that the agriculture industry has been faced with. The ability for producers to lower costs associated with labor needs and requirements as well as the ability to develop animals in a pasture or range scenario has increased producers interest in using self-fed supplements (Kunkle et al., 1997). Many cow/calf producers offer protein supplement to cattle grazing nutrient deficient dormant range. Cattle grazing low-quality roughages will benefit most by being supplemented with protein if forage amount is not limited (DelCurto et al., 2000). Producers have many different forms of supplementation available through the commercial feed industry; most commonly is blocks, tubs, and liquids (Kunkle et al., 1997). Self-Fed supplements contain multiple limiters to control animal intake (Kunkle et al., 1997; Bowman and Sowell, 2002). Baked Molasses protein blocks are a convenient product for cow/calf producers to use as a supplementation method because of reduced labor and access to extensive rangelands. Intake variation is a known challenge with these products (Bowman and Sowell, 1997a).

Performix Nutrition Systems, LLC, approached us about working with their self-fed protein supplement products and to specifically characterize variation of supplement intake of two products; Bovibox and Bovibox HM. One key difference in these two products is the level of magnesium. It is common practice to use magnesium oxide, as well as salt as limiters in self-fed molasses blocks (Kunkle et al., 1997; Bailey et al., 2008). These products use these same ingredients as a self-limiter. The High magnesium level of the Bovibox HM increases the bitterness, as compared to the Bovibox. Variation of intake is known to exist in these products and variation differs from ranch to ranch (Bowman and Sowell, 2002). Factors hypothesized on label to be influencing variation in supplement intake include weather, forage availability, body condition of cattle, and/or availability of other feeds. Intake of supplement can be altered by increasing or decreasing the number of blocks per pasture, moving closer or farther from watering locations, shade or loafing areas, or by providing other supplemental feeds. With grazing ewes, Ducker et al. (1981) stated that the number of non-feeders of molasses-urea blocks increased as the grazing area per ewe increased. Additionally, Bowman and Sowell (1997a) suggested that supplementation characteristics such as hardness and nitrogen content may influence variation in consumption. We specifically want to look at variation of block Magnesium levels and the effect that the availability of free choice salt and/or trace mineral salts can have on supplement intake.

Research on the variation of protein supplement intake in a grazing setting is limited (Bowman et al., 1995; Wyffels et al., 2019). This research provides the industry with additional research on the impacts of form between two different protein block formulations and adds new insight on the effects protein block supplements can have on supplement intake behavior and performance with heifers grazing dryland pastures.

CHAPTER TWO

LITERATURE REVIEW

Ruminants: A highly adapted species

Ruminants have a highly developed and specialized digestive track that allows them access to energy from fibrous feed stuffs and have evolved to be able to maximize the utilization of forages and vegetation which produce the most abundant carbohydrate, cellulose (Van Soest, 1982). The ability for ruminants to digest cellulose, via microbial fermentation, results in the ability to unlock otherwise unavailable food energy found from cellulose, which other non-ruminants are not able to digest (Van Soest, 1982; Bowman et al., 1995). Most of our planet's rangelands consist of forages that are bulky, fibrous, and are relatively low in digestible energy (Moore et al., 1999). Ruminant animals, wild and domestic, are uniquely suited to utilize these landscapes (Van Soest, 1994).

Beef production is an extremely important facet to the global economy and represents the number one agricultural commodity produced in the United States and the State of Montana (NASS, 2019). Livestock production in the western U.S. relies heavily upon rangelands for beef cattle production (DelCurto et al., 2000; Tanaka et al., 2007). Pasture and rangelands represent 66.2% of all land used for farms and ranches (NASS, 2019). However, many western rangelands are characterized by short growing seasons, high elevations, and the arid to semi-arid climates that are highly variable with considerable variation from season to season and year to year (DelCurto et al., 2000; Parsons et al., 2003). Ruminants, because of their ability to utilize low-quality high-fiber forages, are the most important animal resource due to the ability to harvest these rangeland forage resources (Van Soest, 1994).

The Need for Supplementation

Rangeland plants, particularly during senescence, often do not meet livestock nutrient requirements (Krysl and Hess, 1993; Bowman et al., 1995). With high-fiber, low-quality forages, an animal's voluntary consumption is limited by the amount of forage that can physically be consumed (Allison, 1985). In turn, the rate of breakdown, and subsequent passage rate of low-quality forages set the physical limits on the intake (Van Soest, 1994). The nutritive quality of rangeland plants varies due to location, soil types, climate conditions, and precipitation (Bohnert and Stephenson, 2016). Homogeneous plant species are thus subject to differing chemical compositions, often because of varying conditions found on diverse rangelands (DelCurto et al., 2005). The chemical Composition (forage quality estimates) of plants change with season and plant maturity and is often altered by environmental changes such as moisture, drought, and grazing pressures (Allison, 1985; Suttle et al., 1996). Proportion of warm and cool season forages available also effects nutritive composition of selected diets (Adams et al., 1996). These factors, as well as the physical barriers of the ruminant stomach, limits total intake and quality of ruminant diets (Allison, 1985; Adams et al., 1986). Therefore, producers must adapt to wide ranges of forage quality and quantity (DelCurto et al., 2000).

Arid to Semi-arid rangeland forage resources coupled with modern day production expectations necessitates the need for supplemental inputs for beef cattle production (DelCurto et al., 2000; Bohnert and Stephenson, 2016). Seasonal deficiencies of nutrients are frequent in rangelands utilized by beef cattle (DelCurto et al., 1991). Forages available on dormant rangelands are high in fiber and deficient in crude protein (CP) and energy (Brandyberry et al., 1992). Forages not sufficient to provide livestock with required nutrients to meet production goals necessitates the need for supplementation to meet the animal requirements and performance expectations (Stafford et al., 1996; Bowman and Sowell, 2002; Bailey and Welling, 2007). The primary focus of many supplementation programs is to allow producers to extend grazing into the dormant season (Bagley, 1993; DelCurto et al., 2000; Bailey, 2004).

Protein Versus Energy

Conventional supplementation programs include concentrate feeds (cereal grains) composed of non-structural carbohydrates (Sanson and Clanton, 1989). Energy supplementation (high starch cereal grains) typically increase cost of production (Kartchner, 1980; Adams, 1991). This is due to the expense of harvesting concentrates as well as equipment required to feed the concentrates (Adams et al., 1996). Supplementation with concentrates high in non-structural carbohydrates have also resulted in depressed animal intakes and digestibility of low-quality forages (Chase Jr and Hibberd, 1987). However, at times when cereal grain prices are low and forage is limited in supply and/or availability, corn and other grains maybe fed as a concentrate supplement (Sanson et al., 1990). Likewise, when high-quality forages are supplemented with corn, animal performance has increased; while low-quality forages supplemented with corn has seen decreases in animal performance due to reduction in intake and fiber digestion (Sanson and Clanton, 1989).

Supplementing concentrates have been found to alter grazing activities and reduce time spent grazing resulting in decrease of forage intake and sequentially decreased digestibility of low-quality forages due to substitution by concentrates (Chase Jr and Hibberd, 1987; Olson et al., 1999; Brosh, 2007). Beef cattle grazing dormant forages supplemented with corn or barley has shown to decrease forage digestibility and lower intake (Kartchner, 1980). Although forage digestibility decreases when concentrates are supplemented, Sanson and Clanton (1989) found that cattle supplemented with whole shelled corn had no significant effect on animal performance. Furthermore, Sanson et al. (1990) found that when supplemented level of corn increased from .26% of BW to .52% of BW, a 17% decrease in intake and 21% decrease in digestibility of low-quality forage was observed. While the addition of degradable intake protein (DIP) to concentrate supplements has shown an increase in utilization of dormant forages (Bodine and Purvis, 2003).

Dormant season grazing usually consists of animals consuming low-quality dormant forage which by nature is deficient in crude protein (<7%; DelCurto et al., 2010). It has been reported that protein supplementation can increase gain in growing cattle and improve mature cow body weight and body condition during dormant season grazing (Clanton, 1982). Supplementation of protein can increase forage intake, as well as increase forage digestibility which is most seen when forage is below <7% (DelCurto et al., 1990; Bowman et al., 1995; Moore et al., 1999). If protein levels are adequate in forage protein, supplements may have minimal effects (George et al., 2008). Research has found that feeding grain-based energy supplements tends to decrease forage intake and utilization, unlike feeding low-to-moderate amounts of protein which may increase forage intake and utilization of low-quality forages (Bodine et al., 2001; Bodine and Purvis, 2003). Increased forage intakes were reported in steers offered alfalfa pellets when compared to alfalfa hay or soybean meal-grain sorghum (DelCurto et al., 1989; DelCurto et al., 2000). They also found that digestible dry matter intakes were similar in the two alfalfa groups when compared to the soybean-meal supplement (DelCurto et al., 2000).

Daily supplementation requires significant labor and can also require expensive equipment (Bailey et al., 2001). Less frequent supplementation of protein has been found to be successful in ruminants because of their innate ability to recycle N (Beaty et al., 1994). It has been reported that cattle can be supplemented with high-protein supplements less frequently with minimal effect on animal performance (Wallace, 1988; Beaty et al., 1994). In a study utilizing fistulated beef steers on an ad libitum wheat straw diet; animals were supplemented 10, 20, 30, and 40% CP supplement either daily or three times a week. The results found that straw intake increased with both an increase in frequency and CP levels, but animal performance was minimal between supplementation groups (Beaty et al., 1994). Farmer et al. (2004) found that increasing supplementation frequency improved forage intake but had little measurable impact on animal performance. Although utilization of low-quality forage may be improved with daily feeding it still may be more beneficial for producers to supplement less frequent (Bowman et al., 1995). Being able to lessen supplementation frequency may help aide producers in reducing labor, and equipment costs and thus decrease production costs (Taylor et al., 2002).

In contrast, energy supplementation has found little to no success with less frequent supplementation (Coleman and Wyatt, 1982). It has been noted that less-frequent supplementation has been unsuccessful with feedstuffs containing low to moderate CP (Farmer et al., 2001). Furthermore, Kartchner and Adams (1982) found that when feeding grain-based, low protein supplements to mature cows grazing fall-winter range that animals supplemented daily with cracked corn had greater increases in body weight and condition over animals supplemented on alternate days. This may be due to most energy supplements being grain based (Horn and McCollum, 1987; Guthrie and Wagner, 1988; Adams, 1991). Infrequent supplementation typically requires increased amounts of supplement to be feed for animals to reach daily targeted amount (Loy et al., 2003). Detrimental effects have been seen with feeding large quantities of concentrate due to supplement being readily fermentable (Kartchner and Adams, 1982) which can result in an increased likelihood of digestive disorders such as lactic acidosis and reduced performance (DelCurto-Wyffels et al., 2021).

Mineral and Vitamins

Most dormant season grazing systems focus on protein supplementation (DelCurto et al., 2000) but minerals are also often provided in these systems to ensure adequate reproductive performance (Swenson et al., 2000; Bailey and Welling, 2007). Dormant forages found on most rangelands are often deficient in Cu, Zn, and Na (Ganskopp and Bohnert, 2003). Livestock production in the western U.S. relies heavily upon rangelands for grazing animals, and often rangeland plants may not actually meet livestock nutrient requirements (Bohnert and Stephenson, 2016). Rangeland plants vary in quality and content based upon location, soil types, climate conditions, and precipitation (Paterson et al., 1994). These same plants are thus subject to different mineral compositions (Arthington, 2016). Mineral concentration within plants changes with season and plant maturity as well as environmental changes such as moisture, and drought (Suttle et al., 1996).

Meeting livestock nutrient requirements is essential, as minerals effect every living being and effect the major functions of life (Arthington, 2016). These essential functions include structural, physiological, catalytic, and regulatory processes of the body (Stewart et al., 2016). If these nutrient requirements cannot be met by forage and feedstuffs provided, supplementation may be necessary (Bailey and Welling, 2007). Mineral supplementation of livestock becomes necessary to meet the animal requirements and performance expectations when required nutrients are lacking (Stafford et al., 1996). Cattle may increase their ability to meet mineral requirements by selectively grazing multiple grass and forb species or by water resources, but animal performance will be enhanced by providing minerals year-round (Shirley, 1978; Ganskopp and Bohnert, 2003).

Mineral deficiencies in cattle on dormant range are most often manifested by a lack of production, reproductive failure, and impaired immunity such as respiratory diseases and foot rot (Arthington, 2016). The influence of nutrition during gestation on subsequent calf production and lifetime productivity has been referred to as fetal programming. Preventing deficiencies during gestation will greatly aide in adequate fetal development (Funston et al., 2012a). Heifers that calve early during their first calving season have higher lifetime calf production than those that calve late in the season and thus most often justifies the costs associated with a good mineral program (Lesmeister et al., 1973; Endecott et al., 2013). Maintaining and meeting nutrient status of a cow during gestation can also influence performance of offspring (Wiltbank et al., 1969; Funston et al., 2012a). Meeting required nutrient status in turn may help in overall lifetime performance and progeny health (Funston et al., 2012b).

Supplement Delivery Methods

Cattle production systems primarily utilize grazed or harvested forages to supply required nutrients (Galyean and Goetsch, 1993). Dormant or low-quality harvested forages are high in fiber and are very likely to be deficient in CP and energy (Krysl and Hess, 1993). Cattle grazing dormant or low-quality forages as their only source of nutrients may not be able to reach adequate levels of nutrients to meet animal nutrient requirements or desired levels of performance (Judkins et al., 1987; Moore et al., 1999). Nutrient intake is the most limiting production factor of grazing animals (Hodgson, 1982). Supplementation programs assume that animals consume a targeted amount of supplement, and as such, supplement intake is typically measured by dividing the supplement disappearance by the number of animal days (Bowman and Sowell, 1997b). It has been reported that supplement form and delivery method can impact forage intake and animal performance (Guthrie and Wagner, 1988; Paterson et al., 1994; Bowman and Sowell, 1997a).

Supplements are often classified into 2 groups; hand-fed supplements and self-fed supplements (Bowman and Sowell, 1997a; Bailey et al., 2008; Bohnert and Stephenson, 2016). Producers have many options in respect to supplemental protein feed resources. Some of the most used protein supplements are derived from oilseed by-products such as soybean, canola, and cottonseed meal with other sources that include alfalfa hay, pressed blocks, low moisture blocks, liquid feeds, and range cake (DelCurto et al., 2000; Bailey et al., 2008; Bailey and Jensen, 2008; Bohnert and Stephenson, 2016). Liquid and block supplements are typically classified as self-fed supplements whereas traditional supplements such as hay and cakes are classified as hand-fed supplements (Bowman and Sowell, 1997a).

Hand-Fed Supplements

Producers have multiple high-protein, hand-fed supplement options that have been evaluated as supplemental protein sources (DelCurto et al., 2000). Some of the most studied and used hand-fed supplemental protein sources are oilseed by-products including soybean meal, cottonseed meal, canola meal, sunflower meal, rapeseed meal, crambe meal, as well as other sources including wheat middlings and alfalfa (Coombe et al., 1987; Seoane et al., 1992; Caton et al., 1994). Hand-fed supplements often vary by location, where in the Pacific Northwest and Intermountain west, alfalfa or alfalfa-based products may be the supplement of choice because of availability and pricing, whereas producers in the Midwest or plains regions may have easier access to oil-meal by-products because of the same competitive pricing and availability (DelCurto et al., 2000).

A study evaluating weight gains on growing sheep grazing low-quality grass pasture that were either non-supplemented, supplemented with sunflower meal or, supplemented with a urea-based supplement determined that animals gained weight when offered sunflower meal supplement whereas animals receiving no supplement or the urea-based supplement lost weight (Coombe et al., 1987). Other studies have evaluated three forms of a soybean supplement to evaluate the effect on gain of growing steers consuming low-quality meadow hay (6.5 % CP) they determined that the three variations of soybean all had similar results (Albro et al., 1993). When fed on an equal protein basis, alfalfa pellets were just as effective as cottonseed cake (Judkins et al., 1987). An evaluation of sun-cured alfalfa pellets compared to long-stem alfalfa or soybean/ sorghum grain found that animals receiving the sun-cured alfalfa treatment had higher forage intake and improved cow weight and body condition compared to the other treatments (DelCurto et al., 1990). Likewise, supplemental hays have also been evaluated including a study that compared high quality fescue hay (11.9% CP) to alfalfa hay (19% CP) to beef cows consuming grass straw (4.1% CP) where cows receiving fescue hay treatment performed similar or better than cows receiving alfalfa supplement treatment (Horney et al., 1996).

Trough space is an important factor in a hand-fed supplementation program and can both positively and negatively influence intake variation (Paterson et al., 1994; Bowman and Sowell, 1997a). When trough spacing was decreased from 24 to 4 cm/animal with sheep being supplemented once daily with oat grain, an increase in non-consumers occurred (31%) with the limited amount of bunk space (Arnold and Maller, 1974). In contrast, when trough spacing increased too much with cattle from 91 to 180 cm/cow, dominant cows were observed chasing others away and spent less time-consuming supplement (Wagnon et al., 1966; Sowell et al., 1999).

Hand-fed supplementation requires significant commitment to labor and can often require specialized feeding equipment (Beaty et al., 1994). The ability to decrease the frequency supplements are fed allow producers to decrease time, labor, and equipment demands (Farmer et al., 2001). Research evaluating alternate-day or three-times-weekly supplementation with daily supplementation has shown that effects on livestock performance and forage use are minimal and as a result, supports less frequent feeding practices (Coleman and Wyatt, 1982; Beaty et al., 1994). Other research has also shown that hand-fed supplements may be fed as infrequent as once weekly (Kunkle et al., 2000; Klein et al., 2014; Klein et al., 2015). An evaluation of feeding cottonseed cake twice per week as compared to daily feeding resulted in savings of 60% in labor associated with hand-feeding supplement (Melton and Riggs, 1964). In addition, Farmer et al. (2004) found that the positive effects on animal performance of cattle receiving high protein supplementation while grazing dormant forages are maximized by more frequent supplementation. The same research also found that twice weekly feeding has mild performance penalties compared to the daily hand feeding which supports work done previously on reduce supplementation frequency (Kartchner and Adams, 1982; Beaty et al., 1994; Farmer et al., 2004).

Additional research supplementation studies have indicated that hand-fed supplementation programs may decrease forage intake because of substitution (Sanson and Clanton, 1989; Vanzant and Cochran, 1994). Accompanying research suggested that forage quality, cow body size, supplement type, and supplementation amounts may affect forage intake and substitution by supplementation (Adams et al., 1986; DelCurto et al., 1990b; Stafford et al., 1996). Cows supplemented with distillers grain protein cube once weekly while grazing dormant forages saw a decrease in grazing time that may affect intake of forage (Sprinkle et al., 2019). Hand-fed supplements such as whole corn or barley supplements will decrease intake of forages that are deficient in protein (Lamb and Eadie, 1979; Rush et al., 1987; Sanson and Clanton, 1989). Research evaluating timing of supplementation has shown greater increase of gains when the supplement was fed to stocker cattle during non-grazing periods (Adams, 1985). Although hand-fed supplements may decrease intake of low-quality forages, hand-fed supplements also allow for a more precise control of supplement allowance as compared to self-fed supplements (Bowman and Sowell, 1997; Taylor et al., 2002).

Self-Fed Supplements

Self-fed supplementation programs have gained favor with beef cattle producers (DelCurto et al., 2000), especially those grazing dormant forages or those grazing livestock in locations with steep terrain or other obstacles that limit equipment required for hand-fed supplements (Bailey and Welling, 1999; Bailey et al., 2001). Research has shown that self-fed supplementation can be an effective tool for producers to encourage livestock grazing in underutilized areas in extensive rangelands (Bailey et al., 2001; Bohnert and Stephenson, 2016).

Producers have multiple forms of self-fed supplements available through the commercial feed industry with the most common forms being blocks, tubs, and liquids (Kunkle et al., 1997).

Self-Fed supplements contain multiple limiters to control animal intake (Kunkle et al., 1997; Bowman and Sowell, 2002). Some of these include hardness as well as moderately high levels of salt (White et al., 2019). Salt is used heavily with livestock to assist in regulating intake of feed and supplements (Meyer et al., 1955). Research evaluating intakes of salt have found that ruminants may consume more salt than is required if given ad libitum access (Underwood and Suttle, 1999). Salt has also been found to slightly lower ruminal pH levels, but at no detriment to performance or digestion (Brandyberry et al., 1991; Brandyberry, 1994). Studies evaluating salt as a self-fed supplement intake limiter have been shown to be both effective and non-effective (Pickett and Smith, 1949; Beeson et al., 1957). The inconsistency of results may be due to variation of supplement intake and the lack of technology to measure individual animal intake (Nolan et al., 1974; Williams et al., 2018b; Wyffels et al., 2019).

Liquid supplements can be fed free-choice and have at times been found to be more cost effective than other supplements such as hand-fed cottonseed cake when evaluated on cattle in southern pine forest (Grelen and Pearson, 1977). Studies evaluating animal performance with both cattle and sheep under dry lot conditions being fed low-quality feeds such as hay and straw has observed improved animal performance (McLennan et al., 1991; Stephenson and Bird, 1992). The efficacy of liquid supplements with livestock performance on range conditions have been varied (Bowman et al., 1995). Coombe and Mulholland (1983) reported that mature weathers receiving molasses supplement lost less weight than weathers receiving no supplement when grazing oat stubble. Yearling heifers grazing improved forages in Australia did not have a weight gain response when supplemented with molasses or molasses-urea supplements (Langlands and Donald, 1978). It is assumed that liquid supplements may be a tool to aide livestock into grazing underutilized areas of pastures and range, but limited research has been done to evaluate this application of liquid supplementation (Bowman et al., 1995).

Self-fed protein blocks are also a convenient product for cow/calf producers to use as a supplementation method because they reduce labor typically associated with many other supplementation methods (Bailey et al., 2001). Intake variation is a known challenge with these products (Bowman and Sowell, 1997). In turn, supplement intake is the factor that has the most influence on animal performance (Van Soest, 1982). The goal of a supplement should be to deliver a required nutrient in an efficient, and cost-effective method avoiding as much intake variation as possible (DelCurto et al., 2000; White et al., 2019). Supplement formulation may influence variation by altering characteristics such as hardness and nitrogen (Bowman and Sowell, 1997).

Grazing sheep offered molasses-urea blocks with 17, 20.5, and 24.3% CP found that the coefficient of variation (CV) for individual supplement intake decreased as CP content of the blocks increased (Ducker et al., 1981). Additional research evaluating mixed age cattle herds has found that supplement intake behavior varies across different age classes (Bowman et al., 1999). In addition, recent work in Montana evaluating supplement intake behavior of a mixed age cow herd grazing dormant forage supplemented with protein blocks found that 3- to 4-yr-old cattle had the highest supplement intake and least amount of variation (Wyffels et al., 2020) as compared to older cows.

Managing livestock distribution on rangelands is an important factor in the sustainable use of rangelands and grazing resources (Bohnert and Stephenson, 2016). Using self-fed supplementation as a tool has shown to be beneficial for producers by adding profitability to an operation as well as aiding in better livestock distribution (Bailey et al., 2008; George et al., 2008). Cattle typically will overuse portions near and around water sources and other favorable areas (Parsons et al., 2003). Improved grazing distribution is a beneficial tool for livestock producers grazing rangeland (Bailey, 2004).

Utilizing supplements such as a trace mineral and salt along with developing off stream water sources can be an effective tool for producers to assist in altering grazing distribution of livestock (Porath et al., 2002). Riparian areas have often been identified as places for livestock to overuse as these areas can be preferred areas especially during warmer months such as summer (Marlow and Pogacnik, 1986; Parsons et al., 2003). Riparian areas have been subjected to increased scrutiny as livestock can overuse these areas causing, increased soil compaction, increased soil erosion, as well as deteriorating stream banks and lowering water quality (Porath et al., 2002; Parsons et al., 2003; DelCurto et al., 2005). Alternative grazing practices in these areas will reduce the negative impact that is so often associated with grazing animals (Marlow and Pogacnik, 1986).

Supplementation can alter grazing distribution on rangeland (Ares, 1953) as well as change livestock grazing activities (Adams, 1985). One practice that has seen success in helping distribute cattle and in achieving a more uniform grazing is the use of salt, or salt limited supplements to move and disperse cattle throughout a grazing pasture or paddock (Bailey and Welling, 2007). A study done in the Bears Paw mountains near Havre, Montana compared low moisture blocks and salt for the ability to better manipulate grazing patterns and suggested that low moisture blocks are an effective attractant for manipulating cattle to use more underutilized portions of the pasture and in drawing cattle farther from water sources (Bailey and Jensen, 2008). Similarly, other research has suggested that self-fed supplements can improve cattle distribution and avoids the use of calling all cattle into one centralized location like the hand-fed supplementation method which disrupts the grazing activity (Ares, 1953; Adams, 1985). Cattle can also adjust bedding and resting sites to match location of supplement and water (Bailey, 2004; Bailey, 2005), this also may happen during the fall and winter when forage quality is low. Moving supplement blocks to new locations may further assist in better utilization of dormant forages (Bowman et al., 1995).

Studies evaluating the percentage of non-consumers under range conditions have been extremely limited and thus most research under range conditions have not been able to evaluate individual intake behavior (Bowman et al., 1995). The “ideal” supplement is the one that meets the nutrient requirement of the livestock as well as being economically viable and easy to handle (DelCurto et al., 2000). Most programs assume that all animals consume the targeted supplement amount, although supplement intake variation within a group of cattle can be very costly to producers (Bowman and Sowell, 1997). Lack of information on supplement variation is related to the lack of ability to measure intake of free-choice supplements in extensive production environments on a daily and/or individual animal basis (DelCurto et al., 2010). Advances in the technology of self-contained feed systems has more recently made it possible to acquire accurate, individual feed intake data that includes intake behavior attributes, such as time spent feeding, number of feeding visits per day, and total intake per visit (Reuter et al., 2017; Williams et al., 2018a; Williams et al., 2018b).

Performix Nutrition Systems, LLC, approached us about working with their self-fed protein supplement products and to specifically characterize variation of supplement intake of two products Bovibox and Bovibox HM. One key difference in these two products is the level of magnesium. It is common practice to use magnesium oxide, as well as salt as limiters in self-fed molasses blocks (Kunkle et al., 1997). These products use these same ingredients as a self-limiter. The high magnesium level of the Bovibox HM increases the bitterness, as compared to the Bovibox (Wyffels et al., 2020). Variation of intake of other supplement other than Bovibox is known to exist in these products and variation differs from ranch to ranch (Bailey et al., 2001). Known factors that affect supplement intake are also included on supplement label and include weather, forage, availability, body condition of cattle, and/or availability of other feeds. Supplement intake can be altered by increasing or decreasing the number of blocks per pasture, moving closer or farther from watering locations, shade or loafing areas, or by providing other supplemental feeds (Bowman and Sowell, 1997, 2002). We specifically want to look at variation of magnesium levels and the effect of the availability of free choice salt and/or trace mineral salts on supplement intake.

Research on the variation of protein supplement intake in a grazing setting is limited (Bowman et al., 1995). Our research provides the industry with additional information about self-fed supplements as well as Performix nutrition on supplement intake behavior of the two different protein block formulations. This information will add insight to the effects protein block supplements can have on supplement intake behavior and performance with heifers grazing dryland pastures.

CHAPTER THREE

THE EFFECT OF LOOSE MINERAL AND SALT ON PROTEIN BLOCK SUPPLEMENTATION INTAKE BEHAVIOR WITH FIRST CALF HEIFERS GRAZING LATE SUMMER DRY LAND PASTURE

Contribution of Authors and Co-Authors

Author: T. P. McClain

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

Co-Author: S. A. Wyffels

Contributions: Aided in experimental design, data collections, data analysis, and revisions.

Co-Author: N. G. Davis

Contributions: Aided in experimental design and data collection.

Co-Author: B. H. Carter

Contributions: Aided in experimental design, and revisions.

Co-Author: T. DelCurto

Contributions: Critical in experimental design, data collection, data analysis and interpretation, and revisions for this thesis.

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[T. P. McClain, S. A. Wyffels, N. G. Davis, B. H. Carter, T. DelCurto]

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Abstract

The objective of this study was to examine the effects of free choice loose mineral salt on protein block supplement intake and intake behavior of first calf heifers. A trial was conducted on Montana late summer dryland pasture using forty-eight, pregnant (60 d bred ± 30 d) commercial Angus first calf heifers. Heifers were stratified by weight and, within stratum, randomly allotted into one of two supplementation treatments: 1) free-choice access to protein block supplement (30% CP) with access to loosen mineral and salt; and 2) free-choice access to protein block supplement (30% CP) with no access to loose mineral and salt for a 42-day performance study. Supplement, mineral and salt were provided using a SmartFeed Pro self-feeder system (C-Lock Inc., Rapid City, SD) to measure individual animal supplement intake. Individual animal was considered the experimental unit. Intake expressed as kg per day and grams per kg body weight (BW; $P > 0.05$) average was similar for both supplement treatments averaging 0.447 kg and 0.850 g/kg BW, respectively. In addition, intake rate (grams/min) and time spent at feeder (min/day) were not influenced by supplemental treatment ($P > 0.05$). The coefficient of variation (CV) of supplement intake showed no difference in variation between the two treatment groups ($P > 0.05$). When average supplement intake was regressed against loose mineral salt intake, no relationship ($P = 0.11$; r = 0.36) was observed. However, supplement intake increased and variation of intake decreased in the last half of the grazing period. In summary, availability of loose mineral salt did not have an impact on protein block supplement intake.

Introduction

Ruminants have a highly developed and specialized digestive track that allows them access to energy from fibrous feed stuffs and have evolved to be able to maximize the utilization of forages and vegetation which produce the most abundant carbohydrate, cellulose (Van Soest, 1994). The ability for ruminants to digest cellulose, via microbial fermentation, results in the ability to unlock otherwise unavailable food energy found from cellulose, which other mammals are not able to digest (Van Soest, 1994; Bowman et al., 1995).

Beef production is an extremely important facet to the global economy and represents the number one agricultural commodity produced in the United States and the State of Montana (NASS, 2019). Livestock production in the western U.S. relies heavily upon rangelands for beef cattle production (DelCurto et al., 2000; Tanaka et al., 2007). Pasture and rangelands represent 66.2% of all land used for farms and ranches (NASS, 2019). However, many western rangelands are characterized by short growing seasons, high elevations, and the arid to semi-arid climates that are highly variable with considerable variation from season to season and year to year (DelCurto et al., 2000; Parsons et al., 2003). Ruminants, because of their ability to utilize low-quality high-fiber forages, are the most important animal resource due to the ability to harvest these rangeland forage resources (Van Soest, 1994).

Rangeland plants, particularly during senescence, often do not meet livestock nutrient requirements. With high-fiber, low-quality forages, an animal's voluntary consumption is limited by the physical amount of forage that can be consumed (Allison, 1985). In turn, the rate of breakdown, and subsequent passage rate of low-quality forages set the physical limits on the intake (Van Soest, 1994). These factors, as well as the physical barriers of the ruminant stomach, limits total intake and quality of ruminant diets (Allison, 1985). Therefore, producers must adapt to wide ranges of forage quality and quantity (DelCurto et al., 2000).

Arid to semi-arid rangeland forage resources coupled with modern day production expectations necessitates the need for supplemental inputs for beef cattle production. Seasonal deficiencies of nutrients are frequent in rangelands utilized by beef cattle (DelCurto et al., 2000). Forages available on dormant rangelands are high in fiber and deficient in crude protein (CP) and energy. Forages insufficient to provide livestock with required nutrients to meet production goals necessitates the need for supplementation to meet the animal requirements and performance expectations (Stafford et al., 1996; Bowman and Sowell, 1997; Bailey and Welling, 2007). Protein is typically the primary focus of many supplementation programs and allow producers to extend grazing into the dormant season (DelCurto et al., 2000).

Economic efficiency of cattle production is challenged by high feed and input costs (Meyer and Gunn, 2015). Livestock producers are utilizing strategies that allow for a reduction in production costs, while still maintaining their production expectations. Self-fed supplementation programs have gained favor with beef cattle producers (DelCurto et al., 2000), especially those grazing dormant forages or those grazing livestock in locations with steep terrain or other obstacles that limit equipment required for hand-fed supplements (Bailey and Welling, 1999; Bailey et al., 2001; Bailey, 2004). Research has shown that supplementation can be an effective tool for producers to encourage livestock grazing in underutilized areas in extensive rangelands (Bailey and Jensen, 2008; Bohnert and Stephenson, 2016). Producers have multiple forms of self-feeding supplements available through the commercial feed industry with the most common forms being blocks, tubs, and liquids (Kunkle et al., 1997; Kunkle et al., 2000).

Self-fed supplements contain multiple limiters to control animal intake (Kunkle et al., 1997). Some of these include hardness as well as moderately high levels of salt (White et al., 2019). Salt is used heavily with livestock to assist in regulating intake of feed and supplements (Meyer et al., 1955). Research evaluating intakes of salt have found that ruminants may consume more salt than is required if given ad libitum access (Underwood and Suttle, 1999). Salt has also been found to slightly lower ruminal pH levels, but at no detriment to performance or digestion (Brandyberry et al., 1991). Studies evaluating salt as a self-fed supplement intake limiter have both shown to be effective and non-effective (Pickett and Smith, 1949; Beeson et al., 1957). The inconsistency of results may be due to variation of supplement intake and the lack of technology to measure individual animal intake (Nolan et al., 1974; Williams et al., 2018a; Wyffels et al., 2018).

Studies evaluating the percentage of non-consumers under range conditions have been extremely limited and thus most research under range conditions have not been able to evaluate individual intake behavior (Bowman et al., 1995). The ideal supplement is the one that meets the nutrient requirement of the livestock as well as being economically viable and easy to handle (DelCurto et al., 2000; DelCurto et al., 2005). Most programs assume that all animals consume the targeted supplement amount, although supplement intake variation within a group of cattle can be very costly to producers (Bowman and Sowell, 1997). Lack of information on supplement variation is related to the lack of ability to measure intake of free-choice supplements in extensive production environments on a daily and/or individual animal basis (DelCurto et al., 2010). With modern technology (e.g., automated feed bunks and EID tags), it is easier to acquire accurate, individual feed intake data that may include feed intake behavior attributes (e.g., time spent feeding, number of feeding visits per day, and intake per visit) (Williams et al., 2018a; Wyffels et al., 2018; White et al., 2019). With this technology now available, the objective of this study was to examine the effects of offering free choice loose mineral and salt on protein block supplement intake behavior of first calf heifers grazing late summer dryland pasture. We hypothesize that supplement intake behavior, and overall cattle performance could be influenced by the presence of free choice loose mineral and salt.

Materials and Methods

The use of animals in this study was approved by the Institutional Animal Care and Use Committee of Montana State University (AACUC # 2018-AA09).

A trial was conducted at the Fort Ellis Research Farm part of the Montana State University Montana Agricultural Experiment Stations, located 8 km east of Bozeman (latitude 45˚ 38’ N, longitude 110° 58’ W, altitude 1505 m) which on average receives 41 cm of precipitation per year (US Climate Data). The trial was conducted on late summer dryland pastures predominately composed of smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*). Forty-eight, pregnant (60 d bred ± 30 d) commercial Angus first calf heifers were stratified by body condition and weight and, within stratum, randomly assigned into one of two supplementation treatments: 1) free-choice access to protein block supplement (Table 3.1; 30% CP, 23% salt) with access to loose mineral and salt; and 2) free-choice access to protein block supplement (Table 3.1; 30% CP, 23% salt) with no access to loose mineral and salt for a

42-day performance study. All cows were weighed, and body condition scored (BCS; NASEM, 2016) following a 16-h shrink prior to the initiation of the study and again at day 42.

On days 0 and 42, 10 random 0.25 m^2 plots were clipped in the pasture the heifers were using. All samples were weighed, composited by date, sent to a commercial laboratory (Dairy One, Ithaca, NY) and analyzed for crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), and acid detergent fiber (ADF) (Table 3.2).

Supplement, mineral and salt were provided using a SmartFeed Pro self-feeder system (C-Lock Inc., Rapid City, SD) to measure individual animal supplement intake and intake behavior. The supplementation period occurred from 3 August 2018 to 13 September 2018. Each individual animal was equipped with an electronic ID tag (Allflex USA, Inc., Dallas-Ft. Worth, TX) attached to the ear for the measurement of individual supplement intake, number of visits, visit length, and intake rate using a SmartFeed Pro self-feeder system (C-Lock Inc., Rapid City, SD) which provided a total of four feeding stations. Individual animal was considered the experimental unit.

Statistical Analysis

Preliminary analysis evaluating the length of time between supplement intake readings that constitute a new visit to the supplement feeders suggested that readings more than 30-min apart delineate a new visit (Wyffels et al., 2018). This 30-min duration of time was then validated by visual observations of cattle visits to the supplement feeder.

Data were analyzed using ANOVA including linear mixed models with a mixed model evaluating treatment effects on intake rate, salt intake, and block intake. Individual cow was included as a random intercept to account for the autocorrelation of repeated measurements of supplement intake variables for each individual cow. Least square means were separated using the pairwise method when $P < 0.05$. All statistical analyses were performed in R (R Core Team 2019).

Results

The influence by treatment on supplement intake behavior variables are listed in Table 3.3. Intake expressed as kg per day or grams per kg body weight (BW; $P > 0.05$) were similar for supplement treatments. Intake rate (grams/min), time spent at feeder (min/day) were not influenced by supplemental treatment ($P > 0.05$). The coefficient of variation (CV) of supplement intake also showed no difference by treatment ($P > 0.05$). When average supplement intake was regressed against loose mineral salt intake, no relationship ($P = 0.11; r = 0.36$) was observed (Figure 3.1). Supplement intake did change over time with intake of both supplements increasing for the first 28 days of the intake study (Figure 3.2). However, with a pasture move on d 28, supplement intake declined dramatically with a small increase over the remaining 14 days of the study period.

Influence of trace mineral salt on BW and BCS are listed in Table 3.4. Supplementation treatments did not influence performance of first calf heifers grazing late dryland summer pastures ($P \geq 0.05$). Influence of loose mineral and salt when offered with supplement on body weight and body condition of yearling heifers compared with animals offered supplement only saw no differences ($P > 0.05$, Table 3.4).

Discussion

Although many producers are concerned about intake variation of self-fed supplements when used in group feeding scenarios; their primary focus is on animals reaching production goals which includes reproductive efficiency and kilograms of calf weaned. To reach these goals, however, supplementation goals are focused on getting the correct amount of nutrients into the right animals at the right time. Otherwise, producers may see negative impacts including negative impacts on profitability (Bowman and Sowell, 1997). This however is difficult because of the extensive environments in which cattle are managed (DelCurto et al., 2000; Wyffels et al., 2020). Protein blocks may be a convenient product for cow/calf producers to use as a supplementation method in these extensive environments (Bailey et al., 2001; Bohnert and Stephenson, 2016).

Producers may offer additional supplements such as loose mineral and/or salt to cattle being supplemented with protein blocks (White et al., 2019). Our results indicate that there was minimal to no influence on intake or performance when heifers were offered both trace mineral and block supplement. Previous research, also conducted at the MSU Fort Ellis Research center, evaluating the effects of form and salt on supplement intake behavior discovered high variability in free-choice supplement when evaluating loose vs. pelleted supplement (White et al., 2019). However, with salt-limited loose/pelleted supplements, intake was higher and the variation of supplement intake low than reported in our studies.

It has been reported that cattle offered salt, free choice, can become acclimated or accustomed to high salt levels over extended time periods. A recent study observed individual animal daily intakes of a salt-limited supplement at toxically high levels, with no detrimental effects, thus supporting the hypothesis that cattle can become acclimated to high levels of salt in the diet (Wyffels et al., 2018). In an experiment conducted with both sheep and cattle, three levels of salt were feed to sheep and cattle consuming a high concentrate finishing ration (Meyer et al., 1955). In both groups they observed that there were no differences in gains, but that the control group did have an increased number of choice carcasses. They also found that animals in groups receiving salt, had larger water consumptions presumably to buffer or dilute the ruminal effects of salt (Meyer et al., 1955).

Most programs assume that all animals consume the targeted supplement amount, although supplement intake variation within a group of cattle can be very costly to producers (Bowman and Sowell, 1997). Supplement intake can be altered by increasing or decreasing the number of blocks per pasture, moving closer or further from watering locations, shade or loafing areas, or by providing other supplemental feeds (Bowman and Sowell, 1997, 2002).

In conclusion, this research specifically showed increase of intake as forages became dormant and nutrient requirements of heifers increased. By being uniform in supplement delivery method and in targeting specific goals such as meeting the protein requirements of cattle; producers can minimize intake variation in cattle as well as minimize economic inputs.

Table 3.1. Guaranteed Analysis of protein block supplements. (Contains not more than 9.9% protein from non-protein nitrogen).

Ingredient	Rumax BoviBox	Trace mineral salt
Crude Protein	30 %	
Crude Fat	1.5 %	
Crude Fiber	5.0 %	
Calcium	1.3 %	16.0 %
Phosphorus	0.7 %	8.0 %
Salt	23 %	14 %
Potassium	1.5 %	1.8 %
Magnesium	1.0 %	0.5 %
Manganese	880 ppm	
Zinc	1,100 ppm	4500 ppm
Copper	220 ppm	1100 ppm
Copper (from Chelate)	110 ppm	
Cobalt	16 ppm	
Iodine	25 ppm	
Selenium	3.3 ppm min 3.6 ppm max	40 ppm
Selenium Yeast	1.7 ppm	
Vitamin A	89,949 IU/kg	330,693 IU/kg
Vitamin D	9,921 IU/kg	99,208 IU/kg
Vitamin E	110 IU/kg	

Table 3.2. Forage quantity (kg · ha^{-1}) and quality (%) of late summer dry-land pasture grazed by yearling heifers in Bozeman, MT.[1]

	Production	DM	TDN	CP	NDF	ADF
Pasture						
d 0	1614.2	93.8	58	8.8	56.1	35.1
d 42	986.7	98.3	56	4.7	63.7	40.4

[1] Forage production and quality was estimated at days 0 and 42 using 0.25 m^2 plot frames and 10 plots per sampling time.

Table 3.3. Influence of loose mineral salt offered with supplement, Rumax BoviBox vs. Rumax BoviBox + loose mineral, on supplement intake behavior of yearling heifers grazing dryland pastures.

	Treatment[1]			*P* values
	BoviBox	BoviBox +Loose Min	SEM[2]	Trt[3]
Intake, kg · cow^{-1} · d^{-1}	0.33	0.25	0.04	0.43
Intake, g · kg BW^{-1} · d^{-1}	0.62	0.48	0.09	0.26
Intake rate, g · min^{-1}	51.7	52.3	3.66	0.90
Time spent at feeder, min · d^{-1}	9.74	7.07	1.30	0.16
CV Supplement intake, %	131.00	145.00	6.87	0.18

[1]Treatments are 1). Rumax BoviBox, 2). Rumax BoviBox + loose mineral salt
[2]SEM = standard error of the mean (n=30)
[3]Trt = treatment main effect
[4]Pd = period main effect
[5]Trt x Pd = treatment × period interaction

Table 3.4. Influence of loose mineral and salt when offered with supplement, Rumax BoviBox vs. Rumax BoviBox + loose mineral and salt, on body weight and body condition of yearling heifers grazing dryland pastures

	Treatment[1]		
	BoviBox	BoviBox + Loose Min	SEM[2]
Initial Body Wt, kg	526.75	526.88	7.70
Initial BCS	4.54	4.58	0.13
Final Body Wt, kg	549.18	549.62	8.78
Final BCS	5.08	5.12	0.12

[1]Treatments are 1). Rumax BoviBox, 2). Rumax BoviBox + loose mineral and salt
[2]SEM = standard error of the mean (n=30)
[3]Trt = treatment main effect

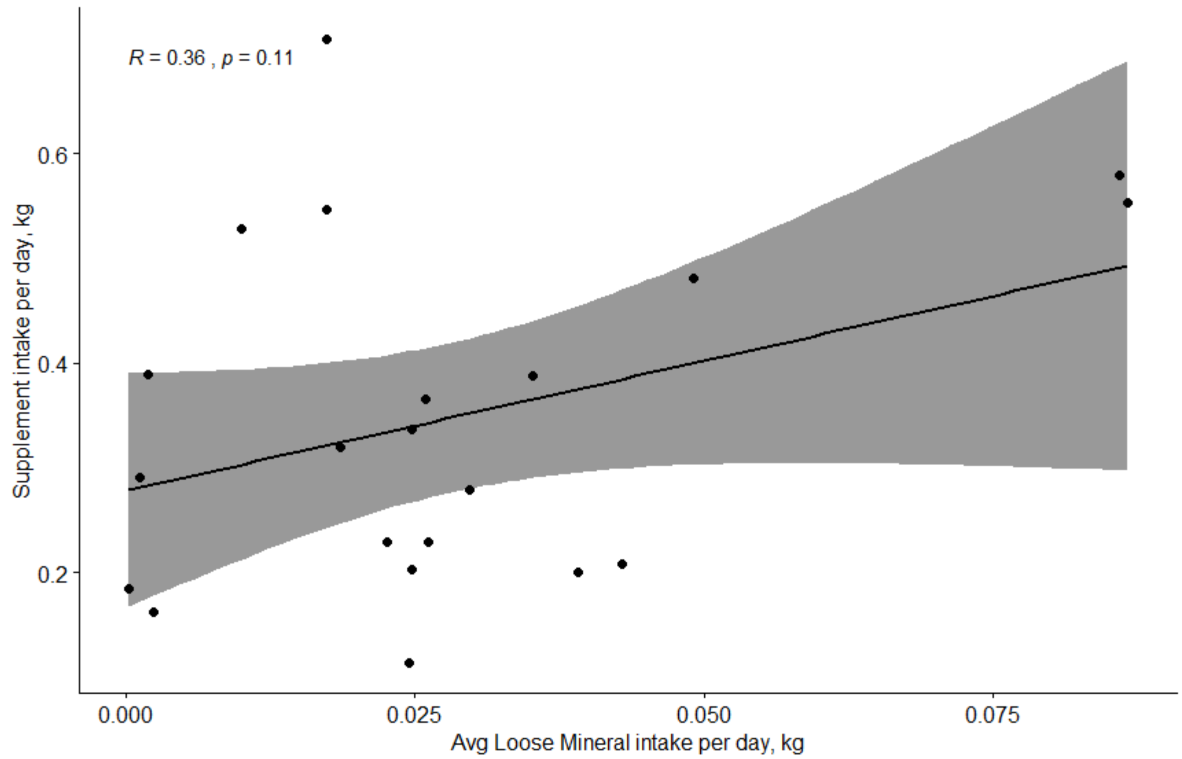

Figure 3.1: Average supplement intake was regressed against loose mineral salt intake, no relationship (P = 0.11; r = 0.36) was observed.

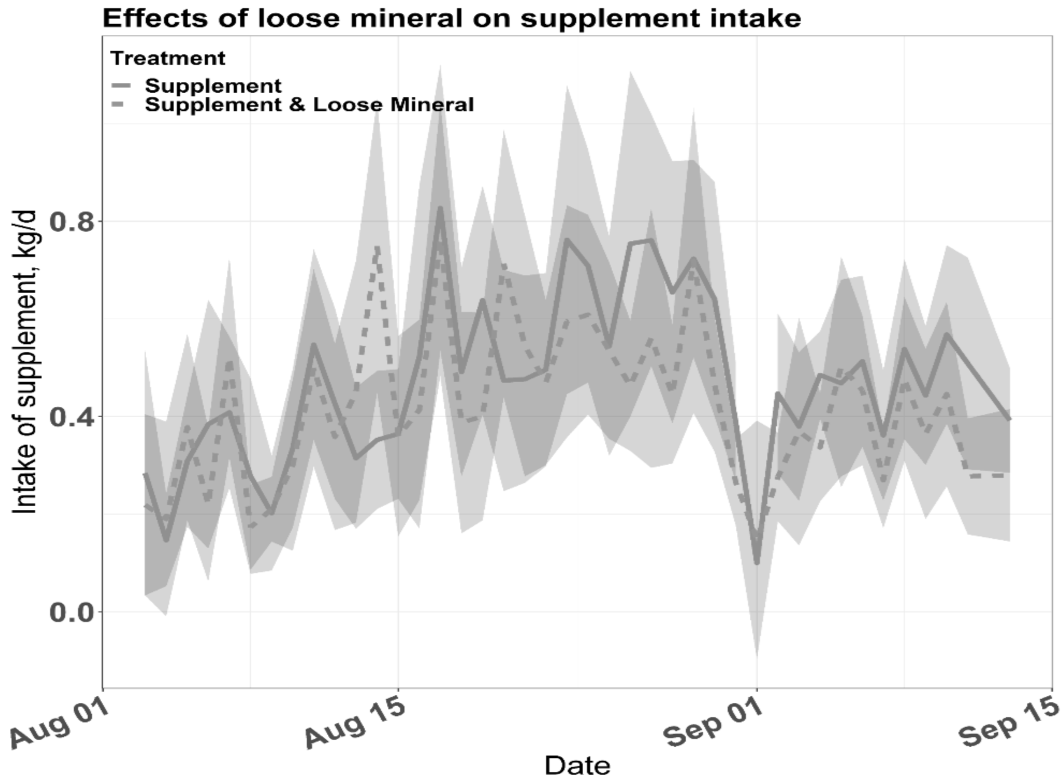

Figure 3.2: Daily intake shown over the 42-day supplement trial.

CHAPTER FOUR

SUPPLEMENT INTAKE VARIATION, WEIGHT, AND BODY CONDITION CHANGE IN YEARLING HEIFERS GRAZING LATE-SUMMER DRYLAND PASTURES WITH RUMAX BOVIBOX VERSUS RUMAX BOVIBOX HM PROTEIN SUPPLEMENTS

Contribution of Authors and Co-Authors

Author: T. P. McClain

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

Co-Author: S. A. Wyffels

Contributions: Aided in experimental design, data collections, data analysis, and revisions.

Co-Author: N. G. Davis

Contributions: Aided in experimental design and data collection.

Co-Author: B. H. Carter

Contributions: Aided in experimental design, and revisions.

Co-Author: T. DelCurto

Contributions: Critical in experimental design, data collection, data analysis and interpretation, and revisions for this thesis.

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Abstract

The objectives of this study were to evaluate Rumax BoviBox versus Rumax BoviBox HM protein supplements on supplement intake behavior, body weight (BW), and body condition score (BCS) change of yearling heifers grazing dryland pastures during late summer. Fifty-nine, yearling commercial Angus heifers (428 kg) were stratified by BW and randomly assigned to one of two supplementation treatments: 1) free-choice access to Rumax BoviBox protein block supplement (30% CP, 23% salt; n = 29); and 2) free-choice access to Rumax BoviBox HM high magnesium protein block supplement (28.7% CP, 23% salt; n = 30). Individual supplement intake, time spent at the feeder, and intake variation were measured throughout the study. On d 0, 42, and 84 heifers were weighed and assigned a BCS following a 16-h shrink. Additionally, forage was sampled every 14 d throughout the study. Supplement intake ($kg \cdot d^{-1}$) displayed a treatment × period interaction ($P < 0.01$). However, within period, treatment differences were not observed with intakes averaging 0.15 and 0.34 $kg \cdot day^{-1}$ for d 0 – 42 and 42 - 84, respectively. Heifers spent more time at the feeder in period 2 than in period 1 ($P < 0.01$) averaging 7.67 vs 4.00 min per day, respectively. Supplement intake rate ($g \cdot min^{-1}$) also displayed a treatment effect ($P < 0.01$) indicating that heifers in the Rumax BoviBox treatment had lower intake rate compared to Rumax BoviBox HM supplemented heifers. In conclusion, there were only minor differences in intake behavior and animal performance with the Rumax BoviBox and Rumax BoviBox HM supplement treatments. However, supplement intake increased and variation in intake decreased with declining forage quality and quantity.

Introduction

Beef production is an important facet to the global economy and is the top agricultural commodity in Montana. In 2019, there were 380,000 replacement heifers developed in Montana, representing 15% of all cattle in the state (NASS, 2019). Proper heifer development needs to be economically managed without sacrificing heifer performance (Funston and Deutscher, 2004). Heifers developed in forage-based systems may provide economic advantages compared to heifers developed on high quality diets in confinement (Funston et al., 2007; Mulliniks et al., 2013). In addition, the high costs of feed associated with developing heifers has encouraged producers to search for alternative methods of reducing the reliance of harvested feeds (Adams et al., 1986; Funston et al., 2007). Effective use of forage-based heifer development systems requires strategic supplementation to offset nutrient deficiencies (Bowman and Sowell, 1997; DelCurto et al., 2000; Bodine et al., 2001).

Producers who are dependent on forage resources for feed must develop strategies that maximize forage use while minimizing supplemental inputs to reduce costs and maintain acceptable levels of beef cattle production (DelCurto et al., 2000). Protein blocks and/or salt-limited supplements are a convenient product for producers because they can increase low quality forage intake and improve animal performance (Horn and McCollum, 1987). Past research has suggested that these supplementation strategies may be limited because of intake variation (Bowman and Sowell, 1997). Livestock managers and supplement manufactures often manipulate salt content, texture, and bitterness to regulate supplement intake. An approach presumed to influence protein block intake is to increase Mg levels of the supplement to subsequently increase bitterness and hardness. However, research evaluating self-fed, free-choice supplements with differing Mg levels in forage-based systems are limited.

Advances in the technology of self-contained feed systems has made it possible to acquire accurate, individual feed intake data that includes intake behavior attributes, such as time spent feeding, number of feeding visits per day, and total intake per visit (Reuter et al., 2017; Williams et al., 2018a; Williams et al., 2018b). Therefore, the objective of this study was to evaluate the effect of Mg levels of two forms of a protein block supplement BoviBox and BoviBox HM on intake behavior and performance of yearling replacement heifers grazing late summer dryland pasture. Therefore, we hypothesize that supplement Mg level will influence supplement intake behavior and animal performance.

Materials and Methods

The care and use of cattle in this study was approved by the Institutional Animal Care and Use Committee of Montana State University (AACUP #2018-AA09). All animals used in this study were provided by the Montana Agricultural Experiment Station.

This study was conducted at Montana State University's Fort Ellis Research Farm located 8 km east of Bozeman, MT (45˚38'N, 110°58'W, 1500 m elevation). Annual precipitation is 470 mm, with 55% occurring during the growing season (May through September). Vegetation is dominated by smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*).

Fifty-nine, yearling commercial Angus heifers (428 kg) grazed five dryland pastures (average 10.5 ha) over 84 days between July 22 and October 14, 2019. All heifers were weighed and body condition scored (BCS; NRC, 2016) following a 16-h shrink prior to the initiation of the study and again at days 42 and 84. Heifers were stratified by BSC and weight (BW) then, within stratum, randomly assigned to one of the following supplement treatments: 1) free choice Rumax BoviBox protein block (Table 4.1.; 30% CP, 23% salt; n = 29); and 2) free choice Rumax BoviBox high magnesium (HM) protein block (Table 4.1.; 28.7% CP, 23% salt; n = 30). Target intake for both supplements was 0.45-0.91 $kg \cdot heifer^{-1} \cdot day^{-1}$. The BoviBox HM is designed for producers with cattle that consume the BoviBox supplement at levels that exceed the target intake.

An electronic identification (EID) tag (Allflex USA, Inc., Dallas-Ft. Worth, TX) was placed in the left ear of each heifer. Supplement was delivered in a centrally located SmartFeed Pro self-feeder system (C-Lock Inc., Rapid City, SD). The SmartFeed system contains four feed bunks mounted on scales, individually equipped with EID tag readers and locking gates. Each treatment was placed in two feed bunks and the SmartFeed system was programed to only allow heifers access to their respective treatment. The SmartFeed system recorded individual supplement intake and time spent at feeder for each appearance at the feed bunks. Using data from the SmartFeed system, we calculated mean daily intake, mean daily intake per unit BW, mean intake rate, mean daily time spent at the feeder, and mean daily intake CV for each heifer for both periods of the study.

Every 14 days, 10 random 0.11 m^2 plots were clipped in the pasture the heifers were using. All samples were weighed, composited by date, sent to a commercial laboratory (Dairy One, Ithaca, NY) and analyzed for crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), and acid detergent fiber (ADF).

Intake, intake per unit BW, intake rate, time spent at the feeder, intake CV, BW change, and BCS change were analyzed in R using generalized linear mixed models that included supplement formulation, period, and a supplement formulation × period interaction as fixed effects and individual heifer as a random intercept (R Core Team, 2019). Each heifer was considered an experimental unit. Least square means were separated using the Tukey method. Statistical significance was accepted at $P < 0.05$.

Results

The influence of supplement formulation on supplement intake behavior variables are listed in Table 4.2. Supplement intake (kg · day^{-1}) displayed a treatment × period interaction ($P < 0.01$). However, within period, treatment differences were not observed ($P > 0.05$), although period intakes differed averaging 0.15 and 0.34 kg · day^{-1} for d 0 – 42 and 42 - 84, respectively ($P < 0.01$). Supplement intake expressed as g · kg BW^{-1} · day^{-1} displayed a period effect ($P < 0.01$) where supplement intake was higher in period 2 than period 1 (0.72 ± 0.04 and 0.34 ± 0.04 g · kg BW^{-1} · day^{-1}, respectively). Supplement intake rate (g · min^{-1}) displayed a treatment effect where intake rate of Rumax BoviBox HM was higher than Rumax BoviBox ($P = 0.02$). In addition, supplement intake rate was 30% greater in period 2 than in period 1 ($P < 0.01$). Time spent at the feeder displayed a period effect ($P < 0.01$) where cows spent nearly twice as much time at the feeders in period 2 than in period 1. Likewise, intake CV displayed a period effect ($P < 0.01$) where intake in period 1 was more variable than in period (218 ± 9.63 % and 163 ± 8.00 %, respectively).

Influence of supplement formulation on BW and BCS are listed in Table 4.3. Change in BW was not influenced by supplement formulation ($P = 0.89$) but was influenced by period ($P < 0.01$) where gain in period 1 was greater than period 2 (33.89 ±1.23 kg and 8.34 ± 1.33 kg, respectively). Change in BCS was not influenced by supplement formulation nor period (*P* ≥ 0.89).

Discussion

When plotting average daily intake over the 84-d trial (Figure 1), supplement intake appeared to be influenced by pasture move dates which, in turn, seemed to be related to forage quality/quantity for each pasture (Table 4.4.). The quality of available forage was only marginally deficient and both forage quantity and quality differed among pastures and over the 84-d study period. Similar to the current study, other researchers have observed forage quality/quantity impacts on supplement intakes with intake increasing with declining forage quality and availability (Wagnon et al., 1966; Ducker et al., 1981; Bowman and Sowell, 1997).

Research relating to individual animal supplement intake in extensive environments such as pastures and rangelands, have only recently been reported. Actual intakes of salt-limited canola base supplements have been found to vary across animal age and forage quality/quantity attributes (Wyffels et al., 2018). White et al. (2019) reported supplement intake behavior with heifers on the same paddocks as our study in previous years also found that intake was higher from d 42 – 84 compared to d 0 – 42 (1.14 vs 0.5 kg per d). In addition, in a two-year winter grazing study in the mixed-grass prairie, Wyffels et al. (2021) reported greater intakes with the BoviBox supplement (yr 1; .45 - .91 kg per d) compared to BoviBox HM supplement (yr 2; < .45 kg per d) with yearling heifers having the lowest intakes and the greatest intake variation (CV) averaging .24 kg/d and 200% CV, respectively. This suggests that yearling heifers in the current study were not as effective at consuming BoviBox supplements and intake may be reduced because of adequate forage quantity and quality.

Implications

Minor effects were observed in supplement intake behavior when comparing BoviBox versus BoviBox HM supplement treatments. However, supplement intake behavior was strongly influenced by period, which could be related to advanced stages of plant phenology where greater daily intakes and reduced intake variation were observed with declining forage quality and availability. Our study suggests that intake behavior of the free-choice supplements changed in relation to forage quantity and quality.

Table 4.1. Guaranteed Analysis of protein block supplements. (Contains not more than 9.9% and 9.7% protein from non-protein nitrogen).

Ingredient	Rumax BoviBox	Rumax BoviBox HM
Crude Protein	30 % min	28.7 % min
Crude Fat	1.5 % min	1.45 % min
Crude Fiber	5.0 % max	5.0 % max
Calcium	1.3 % min	1.3 % min
	1.8 % max	1.8% max
Phosphorus	0.7 % min	0.7 % min
Salt	23 % min	23 % min
		26 % max
Potassium	1.5 % min	1.5 % min
Magnesium	1.0 % min	2.5 % min
Manganese	880 ppm	856 ppm min
Zinc	1,100 ppm	1,074 ppm min
Copper	220 ppm	213 ppm min
Copper (from Chelate)	110 ppm	108 ppm min
Cobalt	16 ppm	15 ppm min
Iodine	25 ppm	26 ppm min
Selenium	3.3 ppm min	3.3 ppm min
	3.6 ppm max	3.6 ppm max
Selenium Yeast	1.7 ppm	-----------------
Vitamin A	89,949 IU/kg	26,455 IU/kg
Vitamin D	9,921 IU/kg	8,818 IU/kg
Vitamin E	110 IU/kg	55 IU/kg

Table 4.2. Influence of magnesium level in supplement, Rumax BoviBox vs. Rumax BoviBox HM, on supplement intake behavior of yearling heifers grazing dryland pastures.

	Treatment[1]			*P* values		
	BoviBox	BoviBox HM	SEM[2]	Trt[3]	Pd[4]	Trt × Pd[5]
Intake, kg · cow^{-1} · d^{-1}				0.43	< 0.01	< 0.01
Period 1	0.13	0.16	0.02			
Period 2	0.36	0.32	0.02			
Intake, g · kg BW^{-1} · d^{-1}				0.34	< 0.01	< 0.01
Period 1	0.30	0.37	0.05			
Period 2	0.77	0.68	0.05			
Intake rate, g · min^{-1}				0.02	< 0.01	0.21
Period 1	25.0	37.9	3.87			
Period 2	41.4	46.4	4.18			
Time spent at feeder, min · d^{-1}				0.63	< 0.01	0.06
Period 1	3.81	4.19	0.57			
Period 2	8.07	7.27	0.59			
CV Supplement intake, %				0.06	< 0.01	0.26
Period 1	237.0	200.0	13.65			
Period 2	164.0	161.0	11.30			

[1]Treatments are 1). Rumax BoviBox, 2). Rumax BoviBox HM
[2]SEM = standard error of the mean (n=30)
[3]Trt = treatment main effect
[4]Pd = period main effect
[5]Trt x Pd = treatment × period interaction

Table 4.3. Influence of magnesium level in supplement, Rumax BoviBox vs. Rumax BoviBox HM, on body weight and body condition of yearling heifers grazing dryland pastures

	Treatment[1]			*P* values		
	BoviBox	BoviBox HM	SEM[2]	Trt[3]	Pd[4]	Trt × Pd[5]
Initial Body Wt, kg	429.00	429.00	4.24	0.97	-	-
Initial BCS	5.38	5.43	0.06	0.49	-	-
Δ Body Wt, kg				0.89	< 0.01	0.21
Period 1	34.06	33.73	1.74			
Period 2	6.21	10.48	1.88			
Δ BCS	0.16	0.16	0.05	0.89	0.99	0.79

[1]Treatments are 1). Rumax BoviBox, 2). Rumax BoviBox HM
[2]SEM = standard error of the mean (n=30)
[3]Trt = treatment main effect
[4]Pd = period main effect
[5]Trt x Pd = treatment × period interaction

Table 4.4. Forage quantity (kg · ha^{-1}) and quality (%) of late summer dry-land pastures grazed by yearling heifers in Bozeman, MT.[1]

	Production	DM	TDN	CP	NDF	ADF
Pasture 1						
d 0	3937.3	93.9	58	8.9	57.7	37.9
d 14	2535.2	94.7	56	7.5	62.6	38.7
d 28	2094.5	97.2	56	5.3	62.4	38.1
Pasture 2						
d 28	2460.3	95.1	60	10.9	49.9	35.5
d 42	1480.8	95.3	56	6.6	61.8	39.8
Pasture 3						
d 42	4412.7	95.3	56	5.6	62.0	39.5
d 56	2611.1	96.9	57	5.5	60.5	36.3
d 70	2794.5	96.1	55	4.6	66.2	42.0
Pasture 4						
d 70	2940.5	94.2	57	10.4	60.1	41.4
Pasture 5						
d 84	3431.2	96.6	55	5.4	68.4	43.3

[1] Forage production and quality was estimated every 14 days using 0.11 m^2 plot frames and 10 plots per sampling time.

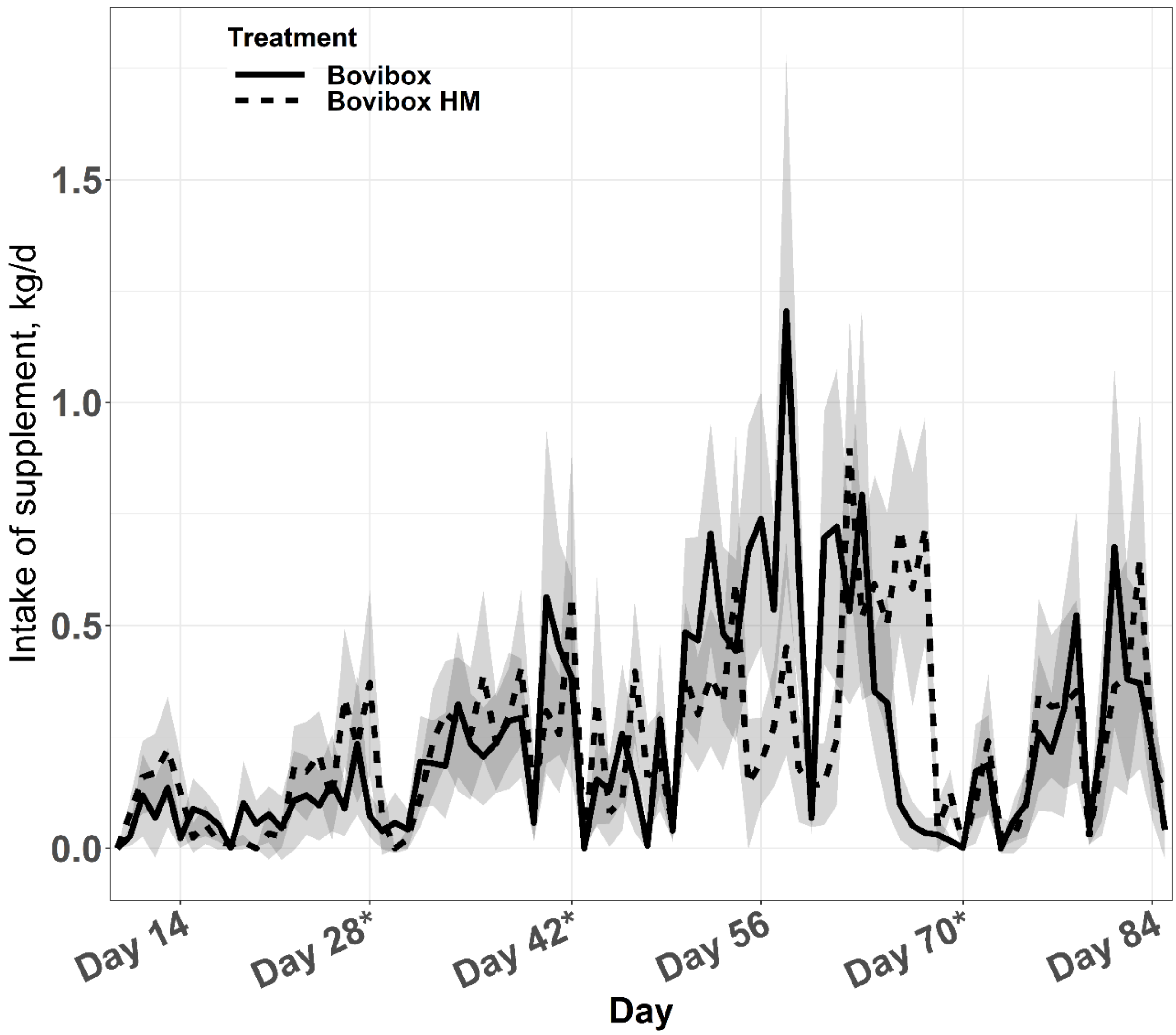

Figure 4.1. Supplement intake behavior of yearling heifers consuming BoviBox or BoviBox HM supplements over an 84- d period on dryland pastures. Asterisk (*) indicates pasture move dates over the 84-d period.

CHAPTER FIVE

CONCLUSIONS AND FUTURE RESEARCH NEEDS

Beef production is an important component to the global economy and is the number one agricultural commodity produced in the United States and the State of Montana (NASS, 2019). Beef cattle in particular, have a highly developed and specialized digestive tracks that allow them to convert energy from fibrous feed stuffs found in all range types (Van Soest, 1982). The ability for cattle to digest cellulose, via microbial fermentation, results in the ability to utilize otherwise unavailable energy found in the form of cellulose (Van Soest, 1982; Bowman et al., 1995). Most of our planet's rangelands consist of forages that are bulky, fibrous, and are relatively low in digestible energy (Moore et al., 1999).

Rangeland plants, particularly during senescence, often do not meet livestock nutrient requirements (Krysl and Hess, 1993; Bowman et al., 1995). With high-fiber, low-quality forages, an animal's voluntary consumption is limited by the physical amount of forage that can be consumed (Allison, 1985). In turn, the rate of breakdown, and subsequent passage rate of low-quality forages set the physical limits on the intake (Van Soest, 1994). These factors, as well as the physical capacity of the ruminant stomach, limits total intake and interacts with quality of cattle diets (Allison, 1985; Adams et al., 1986). Therefore, producers must adapt to wide ranges of forage quality and quantity (DelCurto et al., 2000).

Arid to semi-arid rangeland forage resources coupled with modern day production expectations necessitates the need for supplemental inputs of beef cattle production systems (DelCurto et al., 2000; Bohnert and Stephenson, 2016). Seasonal deficiencies of nutrients are frequent in rangelands utilized by beef cattle (DelCurto et al., 1991). Forages not sufficient to provide livestock with required nutrients to meet production goals necessitates the need for supplementation to meet the animal requirements and performance expectations (Stafford et al., 1996; Bowman and Sowell, 2002; Bailey and Welling, 2007). Protein and or energy are the primary focus of many supplementation programs and allow producers to extend grazing into the dormant season (Bagley, 1993; DelCurto et al., 2000; Bailey, 2004)

The purpose of our research was to evaluate intake behavior and variation of two different protein block sources, as well as, determining the effect of making available a free choice salt and/or trace mineral with the protein blocks can have on cattle performance. Research evaluating variation of protein supplement intake in a grazing setting is limited (Bowman et al., 1995; DelCurto et al., 2010). Our research provides the industry with additional information about self-fed protein block supplements and the inherent supplement intake behavior of the two different protein block formulations. This information adds insight to the effects protein block supplements can have on intake behavior and subsequent performance of heifers grazing dryland pastures.

Our Research included two studies. The first study evaluated the effect that loose mineral and salt could have on protein block supplement intake. We used first calf heifers grazing late summer dryland pasture for this study. In this study we found no difference between intakes of animals offered both mineral and salt and the protein block, as well as heifers offered block only. This supports previous research that found performance of yearlings to be variable among supplements containing salt as a limiter (Chicco et al., 1971; Harvey et al., 1986; White et al., 2019). Our research also suggests that providing a free-choice trace mineral had no influence on intake of the self-fed protein supplements containing salt. However, it was observed that supplement intakes did change after day 28 when heifers were moved into an un-grazed pasture in which we saw supplement intakes decline. Our hypothesis for the decrease of supplement intakes was that the new pasture offered an increase of forage quality causing an effect on supplement intake. Additional research supporting our hypothesis indicates that when protein levels are adequate in forage, protein supplements intakes and affects may be minimal (George et al., 2008). While our research suggests that combining a trace mineral with a self-fed supplement has minimal impacts on supplement/trace mineral free-choice intake. It should also be noted that heifers in study 1 had relatively low intakes of both the trace mineral and protein supplement. Therefore, additional research is needed with higher intakes of protein blocks and salt-levels in the trace mineral to really access the dynamics of two self-fed salt-limited supplements in rangeland settings with low-quality, high-fiber, forage resources.

Our second study evaluated the two most common formulations of the Performix Nutrition Inc., protein supplement; Rumax BoviBox versus Rumax BoviBox HM protein supplements. Specifically, we evaluated supplement intake, intake behavior, and body weight (BW) change over a 84-d summer grazing period. Supplement intake behavior was strongly influenced by period, which could be related to the advancing stages of plant phenology, where greater daily intakes and reduced intake variation were observed with declining forage quality and availability.

Although minor effects were observed in supplement intake behavior in both studies, our results supported previous research that supplement intake behavior can be influenced by period, which could be related to maturity of plants in each paddock. Greater daily intakes and reduced intake variation were observed with declining forage quality and availability later in the grazing duration.

Other research has suggested that animal age can have a significant influence on cow performance, grazing behavior, supplement intake behavior. (White et al., 2019; Wyffels et al., 2019; Wyffels et al., 2020). White et al. (2019) also observed that form of supplement can influence the intake behavior of yearling heifers. One key observation from our study is that heifers in our study did not have intakes of blocks as high as mature cows used by(Wyffels et al., 2020) so, age class may play a particular role in intake behavior.

Information from these studies will add insight to the effects protein block supplements can have on supplement intake behavior and performance with heifers grazing dryland pastures. Although our findings were minor, it allows for future research to be done as we have validated the use of technologies such as SmartFeed Pro Trailers (C-Lock Inc., Rapid City, SD) and their use in pasture settings. Future research should be conducted and replicated using mature cows. As observed in other research conducted with BoviBox blocks mature cows had higher intakes of blocks, replicating this research with higher intakes may show actual relationships of offering salt or mineral to cattle being supplemented with protein blocks (Wyffels et al., 2020).

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