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Evaluation of Precision Ingredient Inclusion on Production Efficiency Responses in Finishing Beef Cattle

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EVALUATION OF PRECISION INGREDIENT INCLUSION ON PRODUCTION EFFICIENCY RESPONSES IN FINISHING BEEF CATTLE

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABBREVIATIONS

ADF	acid detergent fiber
ADG	average daily gain
BW	body weight
CP	crude protein
CRNSIL	corn silage
d	day
DDGS	dried distiller's grains plus solubles
DM	dry matter
DMI	dry matter intake
DOF	days on feed
DP	dressing percentage
DRC	dry rolled corn
EBF	empty body fat
EE	ether extract
EG	daily energy gain
EM	maintenance energy
FBW	final BW
FFG	feed available for gain
FFM	feed available for maintenance
FHP	fasting heat production
g	grams
G:F	gain to feed

GH	grass hay
h	hour
HCW	hot carcass weight
HMC	high moisture corn
Kg	kilogram
LS	liquid supplement
LWG	live weight gain
Mcal	megacalorie
ME	metabolizable energy
MQ	estimated maintenance coefficient
NASEM	National Academies of Sciences, Engineering, and Medicine
NDF	neutral detergent fiber
NE	net energy
NEg	net energy for gain
NEm	net energy for maintenance
RE	retained energy
REA	ribeye area
RF	ribfat
RNC	Ruminant Nutrition Center in Brookings, South Dakota
RY	retail yield
TBA	trenbolone acetate
TMR	total mixed ration
USDA	United States Department of Agriculture

W	weight (kg)
YG	calculated yield grade

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ABSTRACT

EVALUATION OF PRECISION INGREDIENT INCLUSION ON PRODUCTION EFFICIENCY RESPONSES IN FINISHING BEEF CATTLE

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Two randomized complete block design feedlot experiments were conducted over the course of two years. These experiments were conducted to investigate the effects of 1) evaluate the observed-to-expected ratio for ingredient inclusion using no commodity inclusion assistance technology or using commodity inclusion assistance technology; and 2) evaluate the influence that varying degrees (highly variable at random or 0.454 kg as-fed tolerance for each ingredient) of accuracy on ingredient inclusion have on growth performance, carcass traits, efficiency of dietary NE utilization, and ingredient inventory management in finishing beef cattle. Experiment 1 used single source Black Angus heifers (n = 60; initial shrunk BW = 460 ± 26.2 kg). Experiment 2 used single source Charolais-Angus cross steers (n = 128; initial shrunk BW = 505 ± 32.1 kg). Heifers and steers were allotted to 1 of 2 dietary treatments: 1) 0.454 kg as-fed tolerance for each ingredient (CON), or 2) highly variable at random (VAR). In Exp. 1, applying a highly variable at random dietary inclusion did not affect ADG, dry matter intake (DMI), or feed conversion efficiency ($P \geq 0.15$). There were no differences ($P \geq 0.35$) detected between treatments for HCW, dressing percentage, rib eye area, rib fat, USDA marbling score, KPH, yield grade, retail yield, empty body fat, or body weight at 28% estimated EBF. In Exp. 2, highly variable at random dietary inclusion showed an increase in ($P \leq 0.01$) DMI and reduced ($P \leq 0.02$) kg of gain to kg of feed (G:F) for VAR. However, no differences

(P = 0.75) were detected between treatments for ADG. In addition, Net Energy for maintenance and gain was decreased ($P \leq 0.01$) in VAR. Carcass characteristics for both treatments showed no treatment effect ($P \geq 0.38$) on HCW, dressing percentage, rib eye area, rib fat, KPH, Yield Grade, retail yield, empty body fat, or body weight at 28% estimated EBF. A tendency for increased USDA marbling score ($P > 0.08$) was noted in VAR. Under the conditions of this experiment, randomly altering ingredient proportions negatively affected feed efficiency with no change in carcass characteristics.

CHAPTER I: REVIEW OF LITERATURE

1.1 INTRODUCTION

Cattle feeding operations such as feedlots are concentrated in the Great Plains with major numbers located within the corn belt of the United States. Numbers within the Great Plains range from operations with 1000 head or less to large scale operations with a capacity of 30,000 head or more. In response to the worlds growing demand for beef, many have adopted a feedlot system to increase production and efficiency (Perdigão et al., 2018). A feedlot is often the final stage of cattle production where cattle are housed in pens and fed a ration consisting of grain, roughage, and a protein supplement to allow for a carcass that meets USDA Quality Grade requirements of a Select grade or greater. Cattle performance and profitability can, at least theoretically, be related to animals receiving a correctly formulated ration, fed at the appropriate amount, and at the correct time (Yates et al., 2000). For years cattle feeders have used these techniques to ensure the well-being and performance of their cattle. With the growing population and increasing pressure on the environment (Greenwood, 2021) producers are faced with the burden of trying to improve cattle productivity to match beef cattle energy and nutrient requirements to the natural resources available in specific regions (Landis, 2018). The feedlot cattle market can best be described as a ‘derived demand’ a demand of a good or service that is reliant on the input of another (Stillman et al., 2009). As grain prices increase and the price of feeder cattle decrease producers must begin to put a large emphasis on efficiency and management.

Feedlot industries comprise a major portion of US beef production. With most disciplines within the industry specializing in physiology, nutrition, and breeding. However, the production system of the feedlot industry predominantly lacks the incorporation of cattle behavior. Research has shown that the incorporation of cattle behavior discipline would increase production and animal welfare (Stricklin and Kautz-Scanavy, 1984). The objective of the research was to evaluate strategies that Northern Plains cattle feeders could implement to fully optimize production responses in a feedlot setting.

1.2 FEED AND ANIMAL MANAGEMENT OF FEEDLOT CATTLE

Excluding the cost of cattle alone feed cost compromises the largest expense of cattle feeding comprising approximately 75 to 80% of feedlot expenses in the United States (Richards and Hicks, 2007). Maximizing energy intake above maintenance typically produces the most cost effective gain (Stock et al., 1990). Feedlot diets in the Great Plains region have changed significantly since the 1980s where the traditional corn and alfalfa diets were used (Landis, 2018). Currently, cattle feeders are faced with environmental challenges that require changes in agronomic practices. One of these environmental challenges is the reduction in water availability which can change farmers crop decisions and affect the cattle feed supply, thus the use of co-products as feed sources (e.g., distiller's grains, cotton seed) has increased greatly. Undoubtedly the future of the farmer feeder has become much more complicated.

1.2.1 Effects of proper diet formulation in finishing beef cattle

To accurately formulate a feedlot diet, it is important to consider the total days required for the animals to finish (i.e. days on feed), type of cattle, environment, availability of feedstuffs, and animal performance. The modern-day feedlot is unique as the diets of feedlot cattle are regularly formulated or updated to keep up with the growth curve of cattle. These formulations allow for producers to ensure that cattle are gaining the appropriate amount during each stage of their life. This allows for producer to adjust rations based on cattle feeding behavior and feed disappearance by increasing or decreasing feed deliveries to avoid over- or under-feeding the herd which can impact cattle efficiency and profitability of the operation. The basis for most beef cattle diet formulation comes from the National Academics of Sciences and Medicine (NASEM) published nutrient requirements. In the late 1960s Lofgreen and Garrett (1968) introduced a system to express net energy requirements for growing and finishing cattle. This system is still widely used today and provides the basis to determine net energy content of feed and predict cattle performance.

When increasing concentrates in feedlot diets, cattle often show a change in feeding behavior leading attributed to improper management of cattle during this time causing a drop in cattle performance (Perdigão et al., 2018). This is often caused by changes in ruminal ecology during this time. Step up programs are a tool used by most feedlots to help transition cattle to higher concentrate diet. During the transition from a forage based to high grain or concentrate based diet the ruminal microbiota begins a transition. Ruminal fibrolytic bacteria become less prevalent and amylotic bacteria begin to increase in response the decrease in forage and increase in concentrate, respectively (Schwartzkopf-Genswein et al., 2003). On average, a 14-day adaptation period is sufficient for cattle to adapt to the new feedlot diet (Perdigão et al., 2018). It has been demonstrated that beef cattle that were adapted with a step-up program had greater average daily gain than those who did not receive a step-up program. Further, beef cattle that are often not introduced to some type of step up protocol had increased cases of ruminal acidosis compared to animals that were stepped up to the proper finishing diet (Goad et al., 1998). This change in ecology and drop in cattle performance are the reasons why step-up protocols are important for cattle health and efficiency.

1.2.2 Effects of roughage application in finishing beef cattle

Roughages can be defined as feedstuff (e.g., hay or silage) that are coarser and high in fiber and therefore low in total digestible nutrients (Morrison, 1936). Roughage is an essential component to finishing feedlot diets fed to most feedlot cattle in North America (Smith, 2021). Most cattle are familiar with roughages and therefore producers use it as way to encourage intake during transitional periods (Galyean and Hubbert, 2014). Traditionally roughages are used in feedlot diets at a low level to help aid in the prevention of digestive disorders and increase net energy (NE) intake (Galyean and Hubbert, 2014). Optimal roughage level is influenced by grain source, processing method, and roughage source (Kreikemeier et al., 1990). Galyean and Defoor (2003) reported that average NDF level of roughage inclusion within feedlot diets is about 8.9% with typical sources being alfalfa hay and corn silages. This level within feedlot diets is normally limited due to the cost per unit of energy and normally included in feedlot diets at a low level to maintain rumen health and decrease digestive upset (Gentry et al., 2016). The addition of low levels of roughage to high concentrate diets often reduces separation of fine particles within the diet allowing for cattle to easily grasp and eat Smith (2021) which means that each bite from the ration mimics the next; this uniformity helps keep the rumen in homeostasis. Incorporating a roughage source that is both moist and bulky with an intermediate particle size and moderate density helps to improve diet uniformity. Typically the inclusion of roughages at low levels within feedlot diets is often due to their slower rate of passage from the rumen, this aspect causes roughages to be a major limitation when it comes to DMI and over all cattle performance (Zinn and Ware, 2003). Consequently, producers often see a negative response with decreased gains and feed efficiency when feeding roughage in large quantities (Kreikemeier et al., 1990; Bartle et al., 1994).

The increased handling characteristics associated with roughages often discourage their use in greater amounts because of the added cost of storage and management (Brown et al., 2006). In addition, certain regions of the US have low availability of roughages leading to an increased diet cost (Gill et al., 1981). This uncertainty in roughage value presents a large problem for nutritionists when it comes to exchanging roughages in a finishing diet while trying to maintain Net Energy for gain (NEg) and digestive function. Roughage sources within feedlot diets have many different physical and chemical characteristics, however the influence that each of these characteristics has on the feeding value of roughages is still unclear (Defoor et al., 2002). When roughages are exchanged on a basis of their neutral detergent fiber (NDF) it has been shown that DM and NEg intakes can be maintained (Galyean and Defoor, 2003; Arelovich et al., 2008; Salinas-Chavira et al., 2013). Although NDF may allow for the exchange of roughage sources more easily, other factors such as content of hemicellulose and lignin may affect average daily gain (ADG) and gain:feed (G:F) (DiLorenzo and Galyean, 2010). The crude protein (CP) concentration and degradability of roughages vary from each source often affecting supplemental protein sources in high grain diets (Milton et al., 1997). Impacts of roughage type and inclusion level within feedlot diets have been a topic of discussion within the industry regarding animal performance, carcass characteristics and rumen health.

1.2.3 Effect of concentrate diets on finishing beef cattle performance

Compared to roughages, concentrates tend to be more condensed in nature (e.g., grains, wheat, and oats) lower in fiber and higher in total digestible nutrients (Morrison, 1936). In today's market the cost per unit of energy generally favors the use of high concentrate diets. Often when cattle are fed a high concentrate diet diluted by roughage cattle must then increase intake in order to maintain daily gains, hence reducing gain efficiency (Galyean and Defoor, 2003). Because corn or most cereal grains are an inexpensive source of energy, it is advantageous for most feedlot producers to feed cattle high-grain diets rather than a more costly lower-energy diet consisting of greater roughage inclusion (Loerch, 1990). High-concentrate diets containing large amounts of cereal grains not only reduces diet cost but also optimizes efficiency of feed mills because of their minimal storage requirement compared to most roughages (Brown et al., 2006). Although a high concentrate diet may offer benefits in cost, storage, and animal performance, farmer feeders must take time when adapting cattle to a high concentrate diet. Many cattle who are introduced into a feedlot often were fed a forage-based diet prior to arrival. This forage-based diet is deemed as "forage" due to the higher level of feedstuff (e.g. hay or silage) fed to cattle (Smith, 2021). This factor is often why an adaptation or step-up period is often associated with feedlot production. When correctly utilized, step-up diets allow for proper adaption of ruminal microorganisms. Immediately switching from a forage-based diet to a high concentrate diet can create digestive disturbances in cattle that may result in lower overall production or even death (Sip and Pritchard, 1991).

However, this contradicts the findings of Crawford et al. (2022) who evaluated the impacts of feeding high risk calves a high-energy finishing diet during both receiving and finishing period compared to a low energy receiving diet with adaptation to finishing a finishing diet. It was reported that FIN had a greater final body weight (BW) for FIN, ADG, and G:F; however, there were no differences in health outcomes, ribeye area, 12th rib fat thickness, yield grade, quality grade, and liver abscess rate between FIN and REC. Conclusions of this study by Crawford et al. (2022) show that allowing calves ad libitum to a high energy finishing diet right away allows for improved growth performance, reduced cost, with no impact on cattle heath. Other researchers have compared the use of step-up diets and restricted feeding of the finishing diet on d1 (Loerch, 1990; Bierman and Pritchard, 1996). These researchers indicated that restricted use of a feedlot diet on d1 can achieve gains equal to that of step ups or adaptations. However, none of these aforementioned studies assessed metabolic health of feedlot cattle (Loerch, 1990; Bierman and Pritchard, 1996; Crawford et al., 2022). Although each of these options may attribute to a decrease feed cost it should be warranted that the long-term metabolic health has not be thoroughly conducted.

1.2.4 Effects of ionophores application in finishing beef cattle

Ionophores are the most widely used feed additives within the cattle feeding industry (DiLorenzo and Galyean, 2010). The wide acceptance of ionophores across the industry can be associated to their improvement in feed efficiency. Some ionophores depress intake; however, there is an increase in weight gain which is associated with improved feed conversion or G:F (Bergen and Bates, 1984). Monensin was first approved for use in the 1970s and since has been used routinely across the industry. Monensin has gained its following within the industry by not only improving feed efficiency in feedlot cattle but also improving dry matter digestibility, reducing the likelihood of feedlot bloat as well as reducing methane losses associated with feedlot cattle (Goodrich et al., 1984). Research has shown that feeding monensin to ruminants decreases the amount of acetic acid production and increases the amount of propionic acid within the rumen (Poos et al., 1979). Propionate production within the rumen appears to be more energetically efficient than the alternative acetate (Hungate, 2013). Another large contributor to energy production within the rumen is propionate which serves as a precursor for gluconeogenesis. This provided increase in propionate may be directly attributed to the rumen having more substrate for glycolysis, thus yielding more energy (Schelling, 1984). Goodrich et al. (1984) summarized performance data on nearly 16,000 head of feedlot cattle used in trials to document the effects of monensin. Data summarized from the trails showed that cattle fed diets containing monensin gained 1.6% faster and consumed on average 6.4% less feed than those fed no monensin. Additionally, Erickson et al. (2003) reported that feedlot cattle fed monensin showed minimized cases of subacute acidosis. This effect can be mainly attributed to monensin sodium inhibiting major lactate producing bacteria within the rumen (Nagaraja et al., 1981). A further description of the effects of ruminal acidosis is discussed later within the review. Feeding recommendations of monensin to increase weight gain and improve feed efficiency range from 70 to 400 mg/head/daily depending on cattle weight. Cattle that exhibit acute signs of monensin toxicity generally experience loss of appetite, decreased intake, diarrhea, weakness, labored breathing, and death. Cattle that experience monensin toxicity have been shown to later develop heart failure as a consequence of the overdose. Erickson et al. (2003) conducted two commercial feedlot experiments to evaluate the effects of monensin concentrations. Concentrations of monensin varying in each of the two treatments 1) 28.6 mg/kg or 2) 36.3 mg/kg. In each of the experiments, concentration of monensin had no effect on growth performance. The use of monensin in both experiments helped control intake patterns; however, increasing the dose of monensin over current approvals had no effect on animal performance.

1.2.5 Steroidal implant history and performance responses

Growth implants were first introduced to the industry in the 1950s and since then their use in the industry has not changed; implants enhance production efficiency, reduce cost of production, and improve profitability (Reinhardt, 2007). Producers have a wide variety of implant products to choose from depending upon the phase of production (Duckett and Andrae, 2001). Since the 1950s there have been more than 30 commercially available implants that are approved for use in feedlots. The U.S. Food and Drug Administration approves and regulates the use of all growth-promoting implants. Each of these implants can be classified into various categories based on type of hormone, potency, and duration of release. The potency of implants is important to producers when thinking of finishing time of the herd as well as matching their energy intake to anabolic dose. Implant potency can be classified as low, medium, or high potency. The current steroidal implants marketed for cattle fall into three endogenously produced hormone categories; androgens, estrogens, and progestins (Smith and Johnson, 2020). Cattle implants containing trenbolone acetate (TBA) and testosterone are the main androgens

used in feedlot implants, while estradiol (E2), estradiol benzoate, and zeranol are the main forms of estrogens used within feedlot implants. Implants that are driven by estrogen create their response by increasing production and release of the hepatic somatotropin and insulin-like growth factor I. This results in an increase in muscle protein accretion (Reinhardt, 2007). Various implants contain a combination of the two to produce a greater response (Reinhardt, 2007). Implants can not only be broken down into category of hormone secreted but also by the coating of implants. Implants can either be coated or not coated. This coating determines how quickly or slowly the anabolic compound will be released into the animal's blood circulation. These implants are first inserted subcutaneously into the posterior side of the animal's ear. Upon insertion the non-coated implant the 'payout' begins. This payout can be referred to the amount of time the implant takes to release that anabolic compound into the animals blood circulation (Smith and Johnson, 2020). This implant payout can be altered by the coating of the implant administered as well as other polymer that provide a delay in release of the anabolic compound into the animals blood circulation (Smith and Johnson, 2020).
During 2011 the USDA National Animal Health Monitoring System (NAHMS, 2000) conducted a survey looking at the use of implants within feedlots. The study surveyed feedlots with a minimum of 1,000 head capacity in 12 of the leading cattle feeding states. The survey results showed that within large scale feedlots (8,000 or more head) steers that weighed 318kg or more entering a feedlot system were implanted 100% of the time (APHIS, 2013).

There are many costs associated with beef feedlot production within the United States. However, the use of implants has allowed producers to reduce that cost. By implanting in every phase of cattle production (e.g., suckling, stocker, and feedlot) producers are able to benefit from about a $93 value per animal (Duckett and Andrae, 2001).

1.3 FEED DELIVERY EFFECT ON FEEDLOT CATTLE PERFORMANCE

The use of proper feed delivery management has been shown to increase profitability in feed yards by reducing the amount of feed wasted thus improving cattle performance (Bierman and Pritchard, 1996; Schwartzkopf-Genswein et al., 2003). A key component of feed delivery is how cattle in a feedlot system are started on feed. “The eye of the master fattens his cattle” reads the Henry and Morrison Feeding textbook (Morrison and Henry, 1946). Just as a factory must be provided proper energy to yield a product fit for sale and revenue, the ruminant animal operates much the same. For the ruminant animal to be productive, proper nutrition must be provided to maintain all life processes. Feeding cattle within a feedlot setting is a dynamic process that must take many factors into account. This portion of the review will discuss several that play an integral part in cattle performance and production.

1.3.1 Effect of bunk management on finishing beef cattle performance

Bunk management is not a new concept within the feedlot industry (Mumford, 1908; Morrison and Henry, 1946; Hungate, 2013). The process of bunk management is a dynamic process that must take many aspects into account (e.g., type of cattle, weather, diet). The system aims to precisely match intake to cattle appetite restricting feed deliveries to feedlot cattle. This restriction allows for feed bunks to be empty at least once each day decreasing feed waste while still increasing cattle performance (Bierman and Pritchard, 1996; Pritchard and Bruns, 2003). The goal of this restricted feed delivery is to improve cattle performance by reducing digestive disturbances (e.g., bloat or acidosis) that can commonly be associated with over feeding of feedlot rations (Schwartzkopf-Genswein et al., 2003). Unlike ad libitum feeding where cattle have continual access to feed restricted feeding or bunk management provides cattle with the amount of feed that they can handle, not the amount they desire. With an end goal to have cattle achieve a long-term average DMI that in time will meet or exceed that of ad libitum feeding (Pritchard, 1993). Fluctuations in intake are commonly associated with ad libitum feeding and can often cause acidosis or reduced DMI. This theory can be supported in a study by Galyean et al. (1992) in which deliberate 10% feed fluctuations were made to assess variation within feed deliveries. Cattle who received the fluctuation saw reduced gain by 6% and feed efficiency by 7%.

This clean bunk management approach adopted throughout most of the United States cattle feeding regions is assessed on a numerical system from 0 to 4. The system strives for consistency with bunk assessments on a 0 to 4 scale made at the same time each day. A scored of 0 indicates no feed remaining in the bunk while a score of 4 means the feed is virtually untouched with the crown of the feed still noticeable. This daily assessment allows for feed calls to be made to each pen.

Often producers turn away from the use of bunk management as it seems to be a time-consuming process. However, Pritchard (1993) showed the cost analysis of bunk management. When producers can increase DMI by 10% returns increased $11.15/hd. However, alternatively if cattle consume 10% less DM profits will be reduced by $15.25/hd. Once again, this cost was assessed in 1993 and would be almost double in today's market. This cost analysis shows that bunk management costs producers nothing more than time and can increase profits and cattle performance.

1.3.2 Effect of time of feeding in finishing beef cattle operations

Time of feeding can differ amongst operations. Most variations tend to be 1X vs 2X feeding deliveries as well as variations in time of day at which feed is delivered. It should be noted that often these variations are based on operation preference. Implications such as management, type of equipment, and environment can play a large role in how an operation conducts their feed management practice. Many studies have been done to conclude which feeding practice provides the best outcome for cattle production within the feedlot setting. Wilson et al. (2020) fed 64 Angus steers in a 141-day feeding study to assess whether feeding once (1X) or twice (2X) per day affects performance standards of finishing feedlot steers. The 1X study received 100% of their feed in the morning hours while 2X received 50% of their feed in the morning and the other half within the afternoon. The study concluded with no differences in final BW or ADG of both groups. However, the treatments did vary in DMI with a greater overall DMI with the steers fed 1X resulting in a 4% improvement in G:F for steers fed 2X per day. There were no differences in in carcass characteristics caused by daily feeding frequency. Previous research by Soto-Navarro et al. (2000) indicated the same findings where time and frequency of feeding within the feedlot environment had little to no effect on overall animal performance. This would contradict previous work done by (Reinhardt and Brandt, 1994; Pritchard and Knutsen, 1995) suggesting that cattle fed within the afternoon or evening hours on average showed an increase in ADG and feed efficiency compared to those fed in the morning. Feeding delivery within the feedlot environment can be ambiguous Pritchard and Bruns (2003) as the variation amongst many yards is not due to preference but often management. Whether an operation chooses to feed 1x or 2x a daily has little to no effect on overall cattle performance. The main goal of most cattle feeding operations is to moderate feeding behavior and reduce variation in intake.

1.3.3 Feed manufacturing and uniformity within the feedlot

A feedlot that provides both uniformity and consistency will show increased cattle performance and reduce digestive disorders (Bierman, 2008). The basic premise used by all nutritionists when formulating rations is that each aliquot (mouthful) of the diet is balanced with respect to the known requirement of the target animal. Uniformity is a crucial factor that may often be overlooked with most benchmarks created by studies with monogastric species (McCoy et al., 1994; Traylor et al., 1994). However, if nutrient levels are inadequate, either above and or below animal requirements, animal performance can be affected. Poorer feed conversion and intake results in an added cost of production, waste, and in worse cases toxicity to the animal resulting in illness or even death (Stokes, 1997). Because ruminants within feed yards often consume feed in large mouthfuls in multiple meals, poorly mixed rations may not be apparent right away. However, over time, when cattle are being pushed to their near genetic potential and large amounts of grains are added, a poorly mixed or non-uniform ration could be the cause of ruminal disfunction.

Uniformity can be defined as having the same manner or degree of consistency allowing for each animal within a feedlot to consume the same balanced diet (Bierman, 2008). Main factors that contribute to non-uniformity tend to be ingredient characteristics with different physical properties such as; particle size, shape, and density which will be discussed later within the review. Errors in mixing time and order are also critical as they tend to be the leading contributors to non-uniformity within a ration. When diet uniformity or consistency is affected so can cattle growth performance. Research conducted by Galyean et al. (1992) demonstrated the influence of these factors by fluctuating feed intake on feedlot cattle. Galyean et al. (1992) evaluating three treatments in a 84-day finishing period by varying the pattern of feed consumption in feedlot steers. Treatments included 1) constant feed intake 2) 10% daily fluctuation in feed intake 3) 10% weekly fluctuation in feed intake. Diet fluctuations compared to treatment 1 included 10% greater, equal, 10% less, equal, 10% greater. Findings between treatments 1 and 3 reported similar daily weight gain and feed efficiency. However, within treatment 2 the daily fluctuation group noticed daily weight gain decreased by 6.5% and feed:gain (F:G) increased 6.9%. Diets and supplements within a feedlot environment are measured on a continuous basis to ensure that they meet the animal's needs. If this process is not monitored or done correctly like the studies listed above cattle performance and profitability of an operation will be greatly minimized (Bierman, 2008).

The objective of any feed mixing operation is to create a uniform, random mixture of the solid and liquid ingredients in the ration (Behnke, 1996). The use of proper equipment allows for feed ingredients to be mixed in the minimum amount of time without compromising the nutritional value of the ration. There are multiple factors that can influence variation within the mixing process, ingredient particle size, shape, density, as well as time are the main properties that will be discussed in this review. Particle size, shape, and density within the cattle industry is not a topic new to discussion the dairy industry has been studying its effects for years (Woodford and Murphy, 1988; Grant et al., 1990; Beauchemin et al., 1994). Often variation of a ration first occurs at mixing due to ingredients in feedlot diets varying in size, shape, and density. This variation normally allows for larger particles to move more towards the bottom of the mixer while smaller particles (e.g., distiller's grains or grass hay) move to the top. For example, on an as-fed basis corn silage tends to have 33% greater more bulk density than that of haylage (Stokes, 1997). Smerchek et al. (2020) demonstrated that as particle size increased (< 4mm), a decrease in cumulative ADG was shown. In a study by Grant et al., (1990) cows fed a fine ration with smaller particle size of hay had decreased ruminantion time; further, they had lesser ruminal pH, less ruminal propionate, and decreased plasma glucose. The use of loading sequence may help minimize the effects of variation caused by differences in particle size, shape, and density. However, most feedlots tend to adopt mixing procedures based on convenience, as it may be more desirable for them to add one ingredient before another. This convivence is often why an emphasis is put on appropriate mixing time. When striving to achieve an accurate and uniform ration to feed cattle proper mixing time must be considered. Insufficient mixing time can alter final diet composition (Stokes, 1997). Rations that are often over mixed can cause considerable break down of fiber particles, while rations that are under mixed can impact cattle consumption and gain. Manufacturers recommend that a ration should be mixed for three to six minutes (Stokes, 1997). The University of Wisconsin surveyed 49 dairy herds showing that the average mixing time was 16 minutes with times ranging from 2 to 60 minutes (Possin et al., 1994). This variation in mixing time can be associated with different feed ingredients, feed additives, and management decisions. In general, when diets are adjusted, mixing time should be adjusted.

1.4 METABOLIC HEALTH EFFECTS OF FEEDLOT CATTLE

1.4.1 Brief history of feedlot health

Beef cattle on the Northern Great Plains are predominantly finished in a feedlot setting on a high concentrate diet. High concentrate diets have a great economic value for feedlots on improving animal efficiency; however, they can pose a challenge on animal health, particularly digestive disorders. The rumen is remarkable in a sense that it can adapt from a diet of mainly forage to a diet of mainly grains. Nevertheless, because of the rapid fermentation process of grain, there are still many digestive disorders (e.g., acidosis and bloat) that feedlot producers must deal with, particularly during adaption to high-concentrate diets. These digestive disorders have been reported to comprise up to 19.5% to 28.4% of mortalities within the feedlot industry (Vogel et al., 2015). Numerous variables affect performance of feedlot cattle some of which are easier to manage and control such as weight, cattle origin, and genetics (Irsik et al., 2006). However, health of feedlot cattle does not have many benchmarks that allow for ease of management. A variety of factors contribute to metabolic health of feedlot cattle including nutrition, management, behavior, and environmental conditions (Galyean and Rivera, 2003).

1.4.2 Effect of acidosis within feedlots

Ruminal acidosis can be defined as either acute or subclinical acidosis. The severity of ruminal acidosis can be associated with the amount of time the animal's ruminal pH spends below 5.2. Acute or subclinical acidosis often results from an excessive intake of rapidly fermentable feeds which causes a fast drop in ruminal pH. In most causes this large change in ruminal ecology is most profound when cattle are transitioned from a forage-based to a grain-grain based diet which is commonly associated with most feedlots. Often improper transition or a lack of an adaptation period is associated with the rumen's papillae being underdeveloped and unable to absorb large quantities of volatile fatty acids (VFAs) that are associated with high concentrate diets. Acute acidosis is often more prevalent during the adaptation period causing an abrupt drop in pH triggering ruminal lactic acid concentrations to rise; as a result, the animals' body signals to reduce feed intake in hopes to urge the reduction of acid absorption ultimately leading to fatal consequences (Owens et., 1998). Due to the accumulation of lactate within the rumen, there is an increase of osmolarity. This increase in osmolarity causes the osmotic pressure of the rumen to exceed that of blood leading to a concentration gradient and influx of water to the rumen (Meyer and Bryant, 2017). This high osmotic pressure and influx in water can often lead to diarrhea and dehydration later damaging the ruminal epithelium causing rumenitis. Clinical signs of acute acidosis include but are not limited to anorexia, lethargy, abdominal pain, and even death. Consequently, cattle that end up surviving the systemic effects of acute ruminal acidosis are shown later to succumb to other complications (Radostits et al., 1994).

Both acute and subclinical acidosis are associated with the ingestion of large amounts of easily fermentable carbohydrates often associated with high grain diets or feedlot rations (Owens et al., 1998). Both acute acidosis and subclinical can arise even after the adaptation period whenever depressed pH occurs. These periods of depressed pH normally range between acute and chronic acidosis, approximately 5.5 to 5.0; (Garrett et al., 1999). Signs of subclinical acidosis may not present themselves for weeks or even months making it difficult for producers to notice. Producers often indicate subacute acidosis with abnormal or sporadic feeding behavior by cattle. In many cases subacute or mild acidosis can be associated with loose stools, anorexia, and decreased feed intake. Producers often notice subclinical acidosis occur with diet changes or abrupt weather alterations (Meyer and Bryant, 2017) . Upon diagnosis, nutritionists and managers should begin with a feed evaluation and diet alteration. Typically, standing cattle that have been diagnosed should be offered grass hay and water monitoring their status until they become stable. Limited research is available on getting affected cattle back up to their finishing diet. It has generally been noted that those cattle who are diagnosed with this condition rarely return to previous intake and performance levels.

Cattle that suffer from an acidotic event should be evaluated on a case-by-case basis. However, in many cases, salvage for slaughter should be considered for those that do not respond or return to previous performance levels. It has been estimated that subclinical acidosis on average cost the dairy industry US$ 2 billion a year (Donovan, 1997). Cattle feeders are in a competitive market with a sole objective of making a profit and as a result cattle must be pushed to their near genetic potential by consuming a high concentrate diet (Elam, 1976). However, this push can lead to erratic feeding and soon acidosis which is estimated to cost $25 to $35 per animal due to lost efficiency (Schwartzkopf-Genswein et al., 2003).

1.4.3 Effect of bloat within feedlots

Cattle bloat can be defined as ruminal dysfunction resulting from the accumulation of excess gas within the animal's rumen (Cheng et al., 1998). Gases from microbial fermentation are normally released through the process of eructation; this process is caused by a series of muscular contractions that induce the gas release from the rumen to the cardia and finally released through the esophagus (Cheng et al., 1998).

However, when this process is inhibited, bloat occurs causing an increase in gas within the rumen resulting in intraruminal pressure causing distention of the animals left dorsal abdominal wall. Bloat in feedlot cattle can be classified into two types 1) free gas bloat and 2) frothy bloat. Free gas bloat is commonly associated with a blockage of the esophagus which prevents the eructation of ruminal gases. This form of bloat is often quickly resolved and does not have long lasting effects on the animal. The second type of bloat often referred to as frothy bloat is the leading cause of bloat within the feedlot industry (Howarth, 1975). This type of bloat deals with the formation of foam within the rumen thought to be associated with the rapidly produced fermentation acids and mucopolysaccharides which disrupt the normal rumen function thus promoting the environment for this foam to accumulate (Cheng et al., 1998). This stable foam in turn traps the ruminal gases and inhibits eructation of gases leading to the formation of frothy bloat.

It is estimated that bloat annually costs the United States livestock industry roughly forty million dollars (Lindahl et al., 1957). In today's market this would amount would almost be doubled due to inflation. Bloat can be observed with almost all cattle production settings, however, is a growing problem within the feedlot industry (Vasconcelos and Galyean, 2008). This can often be attributed to the large variations in feed delivery and abrupt diet changes that are common within the feedlot setting. In addition, peak prevalence of bloat often occurs in animals that are at 99 to 120 days on feed Vogel et al. (2015) which can commonly be associated with the final phase of finishing in most feedlot cattle. Treatment of both free gas bloat and frothy bloat vary depending upon severity. Free gas bloat can often be treated with the passage of a stomach tube. The tube should be the in the proper length to reach the dorsocaudal ruminal sac. The tube should be moved back and forth to ensure all gases are relieved. If no gases are present the froth should be examined, and the animal should be treated for frothy bloat. To relieve frothy bloat the animal may be administered mineral oil or dioctyl sodium sulfosuccinate (Meyer and Bryant, 2017). In instances where the animal is severely compromised or cases of a chronic bloat, a trocar or cannula may be administered. Chronic bloaters of free gas bloat can often be relieved with the administration of a trocar or cannula in the left paralumbar fossa. However, in cases of frothy bloat often a standard size instrument is not sufficient alternatively a larger-bore instrument must take its place. The most humane option for animals that fail to respond to treatment should be salvage for slaughtered. Few studies have been done to compare breed related to bloat. However, it may appear that Holstein cattle are more prone to feedlot bloat than native beef cattle. Researchers mainly attribute this to the increased feed intake associated within the Holstein breed. Unfortunately, still today there is no clear indication of determining an animal's vulnerability to bloat. There are clear management strategies to help mitigate the chance of bloat within the herd. By assessing the composition of the diet, we are able to mitigate bloat. With a few steps such as amount of roughage, processing techniques, grain and feed additive sections, feeding schedules, and bunk calling are all just a few management techniques that are cost effective and help stop the problem before it begins (Cheng et al., 1998).

1.5 FEEDLOT CATTLE BEHAVIOR

1.5.1 Brief overview of common feedlot behavior

Rumination, eating, and activity patterns are all behavioral indicators used in feedlots to assess the productivity of individual animals (Bikker et al., 2014). Analyzing cattle behavior in the feedlot environment can provide producers and researchers a useful tool for evaluating the health and welfare of feedlot cattle (Mathias and Daigle, 2018). Understanding typical feedlot cattle behavior can help determine intervention more precisely and accurately (Robért et al., 2011). Feedlot environment is a main factor when it comes to animal health, social hierarchy, stressors, and activity. It is not surprising that cattle in a feedlot perform and behave in a different manner than cattle on pasture. Feedlot cattle tend to show an increase in lying, aggression behavior, and more abnormal behavior than range cattle. However, feedlot cattle not only show different behavioral patterns than range cattle but also have different feeding patterns. Cattle within a feedlot environment often spend less time ruminating, foraging and feeding than range cattle (Daigle et al., 2017). Meneses et al. (2021) noticed that these behavioral patterns in feedlot cattle are a crucial indictor of the animal's regular life as well as health and metabolism. By understanding feedlot cattle behavior producers and researchers are able to use it as a management tool to mitigate or prevent welfare challenges throughout the cattle feeding period (Mathias and Daigle, 2018).

1.5.2 Common activity found in feedlot environments

Cattle are social animals and operate in a herd structure, where they follow a strict social order of follow the leader (Albright, 1993). Cattle often exhibit different temperament and behavior which can be attributed to breed, sex, and environment where that they were raised. Feedlot cattle spend most of their day sleeping, drinking, eating, and ruminating. It has been noted that cattle are generally only drowsy for 7 to 8 h/d and typically use sleep for recuperation and increase their rest/response time (Albright, 1993). Much like humans, cattle operate off a circadian rhythm. This rhythm is triggered by internal clocks that in the absence of external cues repeat a rhythm of about 24 h (Wagner et al., 2021). Disruptions within this rhythm can be closely related to disease, stress, or environmental changes. Veissier et al. (2001) noticed that the biological rhythm of calves tends to be disrupted during weaning because of the environmental stressors that are often introduced during this time. Robért et al. (2011) examined 25 crossbred steers to examine daily, hourly, and animal to animal effects on lying behavior. With the use of accelerometers, they were able to conclude that the steers lying behavior had a distinct association with circadian rhythm. Steers spend on average > 55% of their time lying between 8 pm and 4 am and tended to be most active during feeding periods. Researchers have observed that cattle tend to eat during daylight hours near sunrise and sunset (Hoffman and Self, 1973; Stricklin and Kautz-Scanavy, 1984). Feeding patterns of feedlot cattle or confined cattle generally depend on the physical and chemical properties of the feed. Cattle that consume a diet of mainly grain tend to consume feed more rapidly and infrequently than those who consume a forage-based diet (Beauchemin, 1991). This variation in feeding can also be attributed to feed access and health. Sowell et al. (1998) reported that on average healthy steers spend 30% more time at the feed bunk than morbid steers.

1.5.3 Effects of rumination time and duration in finishing beef cattle

Rumination can best be described as the process of regurgitation, remastication, salivation, and swallowing of feedstuff to reduce particle size for enhanced digestion (Schirmann et al., 2009). Rumination begins when feed is regurgitated from the reticulorumen into the ruminant's mouth (Beauchemin, 1991). This process often occurs as cattle are lying down; however, it can also be exhibited at other times such as while the animal is standing, walking, or nursing. It has been suggested that rumination efficiency can be directly attributed to cattle lying on their left side (Albright, 1993). The combination of the upright posture and esophageal opening above the ruminal fluid level allow for little to no interference with the rumination process. The process of rumination has been noted to be vital for cattle rejuvenation. Just as many humans utilize sleep for this function, rumination provides the same self-stimulatory effects for cattle. Duration of rumination is greatly attributed to feed type, quality, and physical form. Periods of rumination can occur from 10 to 20 times per day with duration from 1 minute to 2 hours (Beauchemin, 1991). The duration of rumination can be affected by a multitude of things such as stress, digestibility of feed, forage quality, and even salvia production. Changes in duration or rate of rumination tend to occur when cattle are exposed to different environments. For this reason, rates or duration differ substantially in range cattle and feedlot cattle. Often feedlot cattle exhibit more time lying with decreased feeding time, and rumination than that of range cattle (Daigle et al., 2017). This decrease in rumination time in feedlot cattle can be mainly attributed to the decreased forage level and particle size associated with feedlot diets. This theory is consistent with the other research where cattle that consumed diets with greater forage inclusion spent more time ruminating (Gentry et al., 2016; Weiss et al., 2017; Tomczak et al., 2019).

Saliva production within the ruminant animal is a large contributor to the rate and duration of rumination. Almost 70% of the water present within the rumen is from the production of salvia Cassida and Stokes (1986) making it of vital importance in rumen ingesta (Yarns et al., 1965). Alternatively, saliva is also an important component in the rumens microbial population providing most of the nitrogen source needed for proper function (Meyer et al., 1964). Saliva also provides the animal with a multitude of other benefits (e.g., buffering agent, bloat preventative, aid in mastication/rumination, and proper gastrointestinal (GI) function). The production of salvia within the ruminant can be affected by a multitude of factors; however, improper composition of the ruminant's diet can further exacerbate the effects (Meyer et al., 1964). The physical composition of most forages is what promotes chewing thereby promoting more salivation (Beauchemin et al., 2008). In general, most feedlots feed a high concentrate diet rather than a forage-based diet. Consequently, feedlot cattle produce a much lower amount of salvia than that of range cattle on a forage-based diet. Cattle that consume a high-concentrate diet only secrete 60 to 70% of saliva compared to animals fed forage-based diets (Bailey, 1961). Much like humans or other animals, saliva plays a large role in feed intake and utilization. Most variation in saliva production can be attributed to diet composition. Increasing the duration of both eating and rumination can increase cattle performance via increased saliva production.

1.5.4 Effect of stress on finishing beef cattle performance

Cattle generally experience increased stress during three periods of their life: at weaning, marketing/transportation, and transition to a feedlot environment. Weaning is a normal process to allow calves to transition into adulthood; during this time calves are denied access to their mother's milk and contact (Loerch and Fluharty, 1999). Calves are soon introduced to a bunk where they will now eat as well as a waterer. Often associated with weaning is marketing and transport. Here calves are generally deprived of water and feed for a period time and introduced to a new environment. Transportation can be a stressor for a multitude of reasons such as overcrowding, poor air quality, noise, and poor sanitation (Loerch and Fluharty, 1999). After transport or weaning calves are soon introduced to a feedlot environment. Here they must acclimate to a new environment including feed, water, new social hierarchy, and pathogens. Arrival at a feedlot normally includes new processing procedures such as weighing, allotment, and vaccinations. This receiving period is often the most critical time for feedlot cattle as this sets the tone for performance Mathias and Daigle (2018); however, this crucial time is often associated with the most stress. It is important to provide the proper management techniques and knowledge to alleviate stress as much as possible.

Stress can be broken down into three acute phases: alarm reaction, resistance, and finally exhaustion. Animals in the alarm phase often exhibit vocalization. In resistance phase, animals are typically characterized by anabolism relating to metabolism. Here we often see animals with an increase in feed intake. This typically occurs in feedlot cattle 2 to 3 weeks after arrival. Finally, the last phase, exhaustion, occurs before the animal can adapt to the stressor. One major issue with stressed cattle is that they often exhibit little to no signs of injury or disease. This association is because of cattle being a prey specie and do not want to be identified as a target to any threat (Noffsinger et al., 2015).

After the receiving period cattle soon become accustomed to an adaptation period that allows calves to slowly transition to a feedlot diet. Although most stress from transport and arrival has been eliminated, it is important to note that other stressors may arise such as adverse environmental conditions. Feedlot cattle in the Northern Great Plains are subject to weather variations and particularly exposed to extreme variations of hot and cold climates. This adverse weather has been associated with numerous mortalities from the heat waves of 1995 and 1999 where feedlots lost on average 5,000 head a year to the winter of 1996 and 1997 where mortalities reached 100,000 head. In the past 10 years these extreme variations in weather have cost the industry $10 to $20 million in economic loses (Mader, 2003). This cost would almost be double now due to inflation in today's market. The extreme stress associated with these weather fluctuations often makes proper feed management the upmost importance. For feedlots to mitigate loss in performance and mortalities during these severe climate changes decisions must be made prior to these weather events occurring. Proper manipulation of diet energy density and intake is at the upmost importance during these variable times (Mader, 2003).

Although proper stress management can be implemented it is also important to ensure calves are in a positive energy balance as soon as possible after receiving them to a feedlot. A key component of cattle performance that is often ignored is how cattle in a feedlot system are started on feed. The ability for producers to predict dry matter intake (DMI) and net energy for maintenance (NEm) is primary factor in limiting variation in performance (Mader, 2003). The most significant impact of stress within feedlots is decreased feed intake influencing immunocompetency (Loerch and Fluharty, 1999).

1.6 SUMMARY TO REVIEW OF LITERATURE

In summary, this review discussed the importance in feedlot cattle feeding, management, and behavior. The US beef industry relies heavily on the production of cattle in feedlots and will continue to do so with the worlds growing population and demand for beef. Due to the varying timeframes of production within the livestock industry it makes it very difficult for producers to change the direction of output quickly.

Often producers are faced with making production decisions well before feed and product costs are known (Stillman et al., 2009). Within this challenging market producers must find intuitive ways to decrease costs but still increase cattle productivity and performance. As discussed within this review, proper cattle management and feeding techniques is important to ensure increased cattle performance, as well as new integral aspects (e.g., cattle behavior) of production to incorporate in hopes to counter effect of an unforgiving market.

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CHAPTER II: EVALUATION OF PRECISION INGREDIENT INCLUSION ON PRODUCTION EFFICIENCY RESPONSES IN FINISHING BEEF CATTLE

2.1 ABSTRACT

Two randomized complete block design experiments were conducted to : 1) evaluate the observed-to-expected ratio for ingredient inclusion using no commodity inclusion assistance technology or using commodity inclusion assistance technology; and 2) evaluate the influence that varying degrees (highly variable at random or 0.454 kg as-fed tolerance for each ingredient) of accuracy on ingredient inclusion have on growth performance, carcass traits, efficiency of dietary NE utilization, and ingredient inventory management in finishing beef cattle. In doing so two studies were conducted using varying sourcing of cattle of different ages and breed.

Experiment 1 was a 112-d finishing experiment conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD using 60 single source, Black Angus heifers (initial shrunk [4% BW = 460 ± 26.2kg). This study used (n= 10 pens; 5 replicate pens/treatment, 10 heifers per pen) assigned to one of two dietary treatments to evaluate animal growth performance outcomes, efficiency measures, and carcass characteristics when varying degrees of ingredient inclusion tolerances were imposed. Treatments included: 1) Normal feeding with 0.454 kg tolerance for all ingredients (Constant) or 2) Variable inclusion strategy where each ingredient was randomly increased or decreased but the targeted as-fed quantity for the daily delivery was met (Variable). Diets consisted of high moisture ear corn (HMEC), dried distiller’s grains (DDGS), and a liquid supplement (LS). Ingredient inclusions were randomized by assigning independently a random integer to DDGS and LS with each integer corresponding to the deviation from

targeted inclusions. As-fed inclusion rates for DDGS and LS varied from formulated targets by -20, -15, -10, -5, 0, +5, +10, +15 or +20%. The HMEC inclusion was adjusted so that the targeted as-fed amount of the diet was delivered daily. Actual DM inclusion was within 5% of expectations 72% of the time in Constant (13 periods/18 periods) and only 27% of the time in Variable (5 periods/18 periods). Data was analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Ingredient inclusion accuracy did not affect ADG, DMI, or feed conversion efficiency in this experiment ($P \geq 0.15$). However, DMI and liquid inclusion rates showed an inverse relationship. There were no differences ($P \geq 0.35$) detected between treatments for HCW, dressing percentage, rib eye area, rib fat, USDA marbling score, KPH, yield grade, retail yield, empty body fat, or body weight at 28% estimated EBF. No differences ($P = 0.84$) were noted between dietary treatments for liver abscess prevalence or severity. Under the conditions of this experiment, randomly altering ingredient proportions did not affect live animal performance, efficiency measures, or carcass characteristics.

A behavior analysis was conducted during Exp. 1. This study used 40 heifers (20 per treatment) to evaluate beef cattle performance and efficiency compared to activity level and rumination time. Four heifers per pen were randomly assigned a Allflex SenseHub ID tag 2 weeks prior to study initiation. Activity and rumination data were collected in minutes and recorded daily by the SenseHub system for the duration of the finishing experiment. Data were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit and block as random effect.

Ingredient inclusion accuracy did not affect time spent ruminating (*P* = 0.70) or activity level (*P* = 0.18).

Experiment 2 used 128 single source Charolais-Angus cross steers (initial shrunk BW = 505 ± 32.1 kg) in a 94-d finishing experiment at the Ruminant Nutrition Center (RNC) in Brookings, SD. This study used 8 replicate pens (16 total pens) with 8 steers per pen assigned to one of two dietary treatments to evaluate animal growth performance outcomes, efficiency measures, and carcass characteristics when varying degrees of ingredient inclusion tolerances were imposed. Treatments included: 1) Normal feeding with 0.454 kg tolerance for all ingredients (CON) and 2) Variable inclusion strategy where each ingredient was randomly increased or decreased but the targeted as-fed quantity for the daily delivery was met (VAR). All steers were fed twice daily with all bunks managed using a slick bunk approach. Ractopamine HCl was fed (300 mg per head daily) the final 28 d. Individual BW measures were captured at processing and every approximately every 35 d. Diets consisted of (DM basis): 63% dry rolled corn (DRC), 15% dried distiller's grains plus solubles (DDGS), 5% liquid supplement (LS), 7% grass hay (GH), and 10% corn silage (CRNSIL). Ingredient inclusions were randomized by assigning independently a random integer to DRC, GH, and DDGS with each integer corresponding to the deviation from targeted inclusions; LS inclusion was held constant. CRNSIL inclusion was adjusted so that the targeted as-fed amount of the diet was delivered each day. As-fed inclusion rates varied from formulated targets by -20, -15, -10, -5, 0, +5, +10, +15, or +20%. Data were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit, block as random effect, and fixed effects of treatment. Ingredient inclusion accuracy showed an increase in

($P \leq 0.01$) dry matter intake (DMI) and reduced ($P \leq 0.02$) kg of gain to kg of feed (G:F) for VAR. However, no differences ($P = 0.75$) were detected between treatments for ADG. In addition, Net Energy for maintenance and gain was decreased ($P \leq 0.01$) in VAR. Carcass characteristics for both treatments showed no significance ($P \geq 0.38$) in HCW, dressing percentage, rib eye area, rib fat, KPH, yield grade, retail yield, empty body fat, or body weight at 28% estimated EBF. A tendency for increased USDA marbling score ($P > 0.08$) was noted in VAR. Under the conditions of this experiment, randomly altering ingredient proportions did impact growth performance and efficiency measures. However, despite the difference did not affect carcass characteristics.

2.2 INTRODUCTION

Cattle performance and profitability can, at least theoretically, be related to animals receiving a correctly formulated ration, fed at the appropriate amount, and at the correct time (Yates et al., 2000). For years cattle feeders have used these techniques to ensure the well-being and performance of their cattle. The basic premise used by all nutritionists when formulating rations is that each aliquot (mouthful) of the diet is balanced with respect to the known requirement of the target animal. Uniformity is a crucial factor that may often be overlooked within the cattle feeding industry with most benchmarks used were created by studies with monogastric species (McCoy et al., 1994; Traylor et al., 1994). However, if nutrient levels are inadequate, either above or below animal requirements, animal performance can be affected. Improper feed conversion and inconsistent intake results in an added cost of production, waste, and in extreme cases, toxicity to the animal resulting in illness or even death (Stokes, 1997). Because ruminants within feed yards often consume feed in large mouthfuls in multiple meals, poorly mixed rations may not be readily apparent. However, when cattle are being pushed to their near genetic potential and large amounts of grains are added, a poorly mixed or non-uniform ration could be the cause of rumen disfunction. High-concentrate diets have a great economic value for feedlots on improving animal efficiency; however, they can pose a challenge on animal health, particularly digestive disorders. The rumen is remarkable in that it can adapt from a diet of mainly forage to a diet of mainly grains. Nevertheless, because of the rapid fermentation process of grain, there are still many digestive disorders (e.g., acidosis and bloat) that feedlot producers must deal with, particularly during adaptation to high-concentrate diets. These digestive disorders have been reported to comprise up to 19.5% to 28.4% of mortalities within the feedlot industry (Vogel et al., 2015).

Assessing animal behavior within the feedlot has become an important benchmark for cattle producers when it comes to making many managerial decisions, while also serving as a contemporary importance in improving animal husbandry (Urton et al., 2005). Understanding typical feedlot cattle behavior can help determine intervention more precisely and accurately (Robért et al., 2011). Rumination and activity patterns are all behavioral indicators used in feedlots to assess the productivity of individual animals (Bikker et al., 2014).

Accelerometer devices are small noninvasive devices that should not influence natural animal behavior and provide producers with real time monitoring of animal activity (White et al., 2008). Today's devices contain an enclosed accelerometer attached to an ear tag or collar providing quantification of various movements such as activity and rumination (Richeson et al., 2018).

The objective of these experiments were to evaluate strategies that Northern Plains cattle feeders could implement to fully optimize production responses in a feedlot setting. In doing so two feedlot finishing experiments were conducted over the course of two years. These experiments were conducted to investigate the effect that varying degrees (highly variable at random or 0.454 kg as-fed tolerance for each ingredient) of accuracy on ingredient inclusion have on growth performance, carcass traits, feedlot animal behavior, efficiency of dietary NE utilization, and ingredient inventory management in finishing beef cattle. The hypothesis was that variability would increase cost of production and decrease growth performance compared to non-variable cattle in the finishing phase.

2.3 MATERIALS AND METHODS

2.3.1 Institutional Animal Care and Use Approval

These studies were conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD, USA between August 2021, and July 2022. The animal care and handling procedures used within these studies were approved by the South Dakota State University Animal Care and Use Committee (Approval Numbers: 2108-043E and 2203-017E for Exp 1 and Exp 2, respectfully).

2.3.2 Animals, Initial Processing, and Study Initiation

In Exp. 1, 60 single sourced Angus heifers (initial shrunk [4%] BW = 460 ± 26.2kg) in a 112-d feedlot finishing experiment at RNC located in Brookings, SD. Heifers were procured from a South Dakota auction facility and received two weeks prior to study initiation. Upon arrival heifers were placed to 10 concrete surface pens (n = 6 heifers/pen) at the Ruminant Nutrition Center (RNC) in Brookings, SD and provided *ad libitum* access to long-stem grass hay and water upon arrival.

Heifers were weighed and processed 3 d after arrival with initial processing including an individual BW measurement (scale readability 0.454 kg), application of a unique individual ear tag, vaccination against viral respiratory diseases (Bovishield Gold 5; Zoetis, Parsippany, NJ), clostridial species (Ultrabac 7/Somubac, Zoetis), and administration of pour on moxidectin (Cydectin, Elanco). Heifers were also administered a terminal implant on d1 (200 mg trenbolone acetate and 28 mg estradiol benzoate;

Synovex Plus, Zoetis). To ensure there were no pregnancies, two weeks prior to study initiation each heifer was ultra-sounded and given a 2 mL dose of prostaglandin F2 alpha (Lutalyse; HighCon, Zoetis). Heifers were weighed, blocked by location (n = 5), and allotted to their study pens (n = 10) two weeks after dosage of prostaglandin.

In Exp. 2, 128 single source Charolais-Angus crossbred beef steers (initial shrunk BW = 505 ± 32.1 kg) were enrolled into a 94-d finishing experiment at the Ruminant Nutrition Center (RNC) in Brookings, SD. This study used 8 replicate pens (16 total pens; 7.25 × 7.25 m; 6.57 m^2 /steer; 90.6 cm of bunk space/steer; n = 8 steers/pen) assigned to one of two dietary treatments.

Initial processing occurred 175 d before study initiation and included: an individual BW measurement, vaccination for viral respiratory pathogens (Bovi-Shield Gold 5, Zoetis, Parsippany, NJ) and clostridial species (Ultrabac/Somubac 7, Zoetis). On d 1 (study initiation) all steers were individually weighed (readability 0.454 kg), applied a unique identification ear tag, and administered a terminal implant (200 mg trenbolone acetate and 28 mg estradiol benzoate; Synovex Plus, Zoetis, Parsippany, NJ). The afternoon following initial processing, all steers were allotted to their study pens (n = 8 steers/pen and 8 pens/treatment).

2.3.3 Experimental Design and Treatments

In both experiments, variability was applied with the necessary goal of provided variation to each ingredient that would commonly be seen within the industry. Amount of variability applied is presented as up to 20% variation in each ingredient. This was determined daily at random with a random number generator. The targeted goal of each experiment was to randomly alter each ingredient proportions by up to 20% to determine if variable diet inclusion has any effect on live animal performance, efficiency measures, or carcass characteristics.

In Exp. 1, pens were assigned to 1 of 2 dietary treatments (n = 5 pens/treatment): Normal feeding of 0.454 kg tolerance for all ingredients (CON) or Variable inclusion strategy where each ingredient was randomly increased or decreased but the targeted as-fed quantity for the daily delivery was met (VAR). A random number generator was used to determine variations each day with variations up to 20% applied to DDGS and LS. HMEC was used to come back to the targeted as-fed amount or scale total of that feed delivery. In Exp. 2, pens were assigned to the same two dietary treatments only differing in number of pens (n = 8 pens/treatment) and ingredients utilized withing the variation. Within Exp. 2, from days 1 to 41 ingredient variations were applied to HMC, DDGS, and GH. DRC was used to come back to the targeted as-fed amount or scale total of that feed deliver. From days 42 to harvest variations were applied to DRC, DDGS, and GH. With CRNSIL used to come back to the targeted as-fed amount or scale total of that feed delivery.

2.3.4 Dietary Management

Composition of the finishing diet fed in Exp. 1 from d 1 to harvest is presented in Table 2.1. The finishing diet consisted of high moisture ear corn (HMEC), oat hay (OH), and dried distiller's grains (DDGS). A liquid supplement (LS) was provided to add 30 g/907-kg of monensin sodium to diet DM along with supplemental vitamins and minerals to meet National Academies of Sciences and Medicine (2016) requirements.

Composition of the finishing diets fed in Exp. 2 from d 1 to 41 and d 42 to harvest is presented in Table 2.2. The finishing diet from d 1 to 41 consisted of high moisture ear corn (HMC), grass hay (GH), dry rolled corn (DRC), and dried distiller's grains (DDGS). From d 42 to 94, HMC was replaced with corn silage (CRNSIL) and DRC as well as lesser inclusion of GH. Similar to Exp. 1, steers in Exp. 2 also received a liquid supplement (LS) provided to add 30 g/907-kg of monensin sodium to diet DM along with supplemental vitamins and minerals to meet National Academies of Sciences and Medicine (2016) requirements.

Bunks were managed using a slick bunk management strategy for both Exp. 1 and 2. Bunks were visually assessed for residual feed daily at 0700 to determine the amount of feed to provide animals. Bunk management amongst studies and treatments was identical for the duration of each finishing experiment. In Exp. 1, fresh feed was manufactured once daily at 0800h for each treatment in a single batch using a mixing feed wagon (2.35 m^3; scale readability 0.454 kg). For Exp. 2, fresh feed was manufactured twice daily at 0800h and 1400h using the same stationary mixer as for Exp. 1. Heifers and steers in both experiments were (Optaflexx 45, Elanco, Indianapolis, IN) at a rate of 300 mg/hd·d-1 for the final 28-d prior to harvest. When necessary, orts were collected, weighed, and dried in a forced air oven at 100 °C for 24 h to determine DM content if carryover feed went out of condition, or was present on weigh days. If carryover feed was present on weigh days, the residual feed was removed prior to the collection of BW measurements. The dry matter intake (DMI) of each pen was adjusted to reflect the total DM delivered to each pen after subtracting dry orts for each interim period.

Diets presented are actual diet formulation and composition are based upon weekly ingredient DM analyses (drying at 60 °C until no weight change), actual assayed nutrient concentrations from weekly commodity ingredient sampling of dry rolled corn, dried distillers grains plus soluble and each experiments forage source for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, and ether extract (EE): method no. and tabular energy values according to (Preston, 2016).

2.3.5 Growth Performance Calculations

In Exp. 1 heifer BW was recorded every 28 days with study termination on d 112. Exp. 2 steers BW was recorded every 30 days with study termination on d 94. BW of each study was recorded during these timeframes for the calculation of average daily gain (ADG) and feed conversion efficiency (gain:feed; G:F). Average daily gain (ADG) was calculated as the difference between final BW (FBW) and initial shrunk BW, divided by days on feed. Efficiency of weight gain (G:F) was calculated by dividing the period ADG by the period daily DMI. Body weights were measured before the morning feeding and a 4% pencil shrink was applied (to account for digestive tract fill) to the initial BW and final BW. Carcass-adjusted final BW was calculated from hot carcass weight (HCW)/0.625.

Carcass-adjusted growth performance was used to calculate performance based dietary NE to determine the efficiency of dietary utilization. The performance-based dietary NE was calculated from daily energy gain (EG; Mcal/d): $EG = ADG^{1.097} \times 0.557W^{0.75}$, where W is the mean equivalent shrunk BW in kilograms National Academies of Sciences and Medicine (2016) from median feeding shrunk BW. Final BW at 28% estimated empty body fatness (AFBW) calculated as: [median feeding shrunk BW × (478/AFBW), kg (National Academies of Sciences and Medicine, 2016)]. Maintenance energy (EM) was calculated by the equation: $EM = 0.077 \times BW^{0.75}$. Dry matter intake is related to energy requirements and dietary NEm (Mcal/kg) according to the following equation: DMI = EG/(0.877NEm − 0.41) and can be resolved for the estimation of dietary NEm by means of the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$, where a = −0.41EM, b = 0.877EM + 0.41DMI + EG, and c = −0.877DMI (Zinn and Shen, 1998). Dietary NEg was derived from NEm using the following equation: NEg = 0.877NEm − 0.41 (Zinn, 1987).

2.3.6 Measurement of rumination and activity

In Exp. 1, four heifers from each pen randomly received an Allflex eSense Flex accelerometer tag in the middle one-third of the left ear on d -14 of the study. The accelerometer tag remained in place throughout the entirety of the study for continuous measurement of rumination and activity time (min). Rumination and activity time data was transmitted from the tag to a receiver and logged into the Allflex Heatitme Pro software program and data were downloaded for analysis upon completion of the finishing study. Time (min) spent ruminating or active was averaged daily and complied weekly for an average total weekly min spent ruminating or active per treatment. Rumination and activity data was recorded for the duration of the finishing experiment with week 9 excluded due to connection issues. Rumination and activity data is reported for a total of 40 animals across a 110-d period; data usage began on d 0 at 0000 h and ended on d 110 at 2400 h. A two-week baseline for rumination and activity level was determined prior to study initiation.

2.3.7 Management of pulls and removals

In both experiments all animals that were pulled from their home pen for health evaluation were then monitored in individual hospital pens. When an animal was moved to a hospital pen the appropriate amount of feed from the home pen was removed and transferred to the hospital pen. If the animal in the hospital returned to their home pen, this feed remained credited to the home pen. If the animal did not return to their home pen, all feed that was delivered to the hospital pen was deducted from the feed intake record for that pen back to the date the animal was hospitalized.

2.3.8 Carcass Trait Determination

In Exp 1, heifers were harvested after 112 d on feed. Heifers were shipped the afternoon following final BW determination and harvested the next day at a commercial abattoir when the population reached sufficient fat cover to grade USDA Choice. Heifers were comingled at the time of shipping and remained this way until 0700 h the morning after shipping. Hot carcass weight and liver abscess scores were recorded during the harvest procedure. Liver scores were classified according to the Elanco Liver Scoring System: normal (no abscesses), A− (one or two small abscesses or abscess scars), A (two to four well-organized abscesses less than 2.54 cm diameter), or A+ (one or more large active abscesses greater than 2.54 cm diameter with inflammation of surrounding tissue). Video image data were obtained from the packing plant for rib eye area (REA), rib fat (RF), and USDA marbling scores. A common kidney, pelvic, heart (KPH) fat percentage of 2.5% was applied to all calculations requiring a KPH%. Yield grade (YG) was calculated according to the USDA regression equation (USDA, 1997). Dressing percentage (DP) was calculated as HCW/(final BW × 0.96). Estimated empty body fat (EBF) percentage and final BW at 28% EBF (AFBW) were calculated from observed carcass traits (Guiroy et al., 2002), and estimated proportion of closely trimmed boneless retail cuts from carcass round, loin, rib, and chuck (Retail Yield, RY; (Murphey et al., 1960). Carcass data was available for all but one heifer within the variable inclusion treatment.

In Exp. 2, all steers were shipped the same day as study termination (d 94) and harvested the following day at a commercial abattoir when the population reached sufficient fat cover to grade USDA Choice. Steers carcass data collection followed the same guidelines as the heifers from Exp. 1.

2.3.9 Statistical Analysis

Growth performance data from both experiments were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC, USA) with pen as the experimental unit. The model in Exp. 1 included the fixed effect of dietary treatment; block (BW) was included as a random effect. The pen served as an experimental unit for all analyses in both studies. Exp. 2 mimicked the statistical analysis of Exp 1 however animals in Exp. 2 were not blocked by BW but rather pen location. The MIXED procedure of (SAS 9.4 SAS Inst. Inc., Cary, NC, USA) was used to analyze DMI, using the fixed effects of treatment, days on feed, and their interaction determined.

Rumination behavior and total activity level were analyzed as repeated measures and the first order autoregressive covariance structure using the GLIMMIX procedure of (SAS 9.4 SAS Inst. Inc., Cary, NC, USA) with the main effects of treatment, day, and their interaction determined for each repeated variable week; block was included as a random effect. Statistical significance was declared at a *P*-value of less than 0.05 (α = 5%) and a *P*-value greater than 0.05 and less than 0.10 considered a tendency.

2.4 RESULTS

2.4.1 Cumulative Growth Performance- Experiment 1

Carcass-adjusted final BW did not differ (*P* = 0.56) between treatments. Dry matter intake was not affected by treatments (*P* = 0.70). Cumulative ADG based on carcass-adjusted performance (*P* = 0.56) and G:F (*P* = 0.96) were also not affected by treatment. There were no differences between treatments for dietary NEm (2.13Mcal/kg; *P* = 0.97) or dietary NEg (1.46 Mcal/kg; *P* = 0.98). Similarly, observed-to-expected dietary NE ratio showed no differences amongst treatments (*P* = 1.00).

2.4.2 Carcass Characteristics – Experiment 1

Carcass and quality characteristics from Exp. 1, are located in Table 2.5. There were no differences (*P* ≥ 0.35) between treatments for any carcass traits measured, including HCW, DP, REA, RF, YG, marbling, KPH, EBF, or AFBW. Quality grades (*P* = 0.14) distributions did not differ between VAR and CON heifers.

2.4.3 Behavior and Rumination Activity- Experiment 1

No rumination x week interaction (*P* = 0.70) occurred between treatments in Exp. 1 (Figure 2.1). No activity level x week interaction (*P* = 0.18) were detected between treatments in Exp. 1 (Figure 2.3). However, there was a trt x week effect for time spent ruminating and active. A 3.5% increase in minutes active and a 4.5% increase in minutes ruminating for VAR this variation can be seen in (Figure 2.2). With a total of a 12-minute difference in VAR spending more time ruminating.

2.4.4 Cumulative Growth Performance – Experiment 2

In Exp. 2, variable inclusion did not influence final BW ($P = 0.72$) between CON and VAR. Dry matter intake was increased ($P = 0.01$) by 8.0% in VAR compared to CON. Cumulative ADG ($P = 0.75$) showed no difference between CON and VAR treatments and G:F improved ($P = 0.01$) by 7.1% in CON compared to VAR. Dietary NEm and NEg were reduced for VAR compared to CON ($P = 0.01$). The ratio of observed-to-expected dietary NEm and NEg were also reduced for VAR ($P = 0.04$).

2.4.5 Carcass Characteristics – Experiment 2

Carcass and quality characteristics from Exp. 2, are located in Table 2.6. There were no differences ($P \geq 0.38$) among treatments for any carcass traits measured in the present experiment, with the exception of marbling score. That trait tended to differ ($P = 0.08$) between CON and VAR with VAR having an increase in marbling (510 compared to 535, respectfully). Dietary treatments in Exp. 2 did not affect distributions of USDA YG or QG.

2.5 DISCUSSION

2.5.1 Animal Growth Performance- Experiment 1

Previous growth performance data investigating the effects of varying diet inclusion levels is limited. Under the parameters of Exp. 1 varying diet inclusion levels did not influence animal growth performance. Previous studies have reported interim data that can be used to compare growth performance results seen in the present study. In one varying diet inclusion related research trail using Holstein cattle with initial BW of 363 kg in 138-d finishing study Zinn (1994) also reported no appreciable differences for growth performance. This response is inconsistent with some previous work by Galyean et al. (1992) where reduced ADG and poor efficiency were observed in cattle fed a variable dietary treatment. Perhaps, daily fluctuation in feed intake by 20% may not be sufficient to adversely affect growth performance in feedlot heifers within the finishing phase.

However, other possible explanations for this lack of response between CON and VAR treatments in Exp. 1 may be attributed to management techniques that were kept consistent. These factors include mixing time, order of delivery, bunk management, time of feeding, feed manufacturing, and uniformity. Uniformity can be defined as having the same manner or degree of consistency allowing for each animal within a feedlot to consume the same balanced diet (Bierman, 2008). Errors in mixing time and order are also critical as they tend to be the leading contributors to non-uniformity within a ration. Rations that are often over mixed can cause considerable break down of fiber particles, while rations that are under mixed can impact cow consumption and gain. Manufactures recommend that a ration should be mixed for three to six minutes (Stokes, 1997). Perhaps, by having a more uniform management system that accounts for mixing time, order of delivery, bunk management, etc. allowed for minimal variation to be imposed as animals physiological and behavioral responses were anticipated (Pritchard and Bruns, 2003).

As a consequence, heifers within Exp. 1 that received the varying inclusion level of either -20, -15, -10, -5, 0, +5, +10, +15, or +20% may have not been a sufficient enough variation with all other management factors being held constant. These results are consistent with the findings of several other studies documenting the effects of intake fluctuation on performance (Zinn, 1994; Soto-Navarro et al., 2000; Schwartzkopf-Genswein et al., 2004). Although the imposed fluctuations within this study are of similar magnitude to natural fluctuations observed in large scale finishing operations (Hickman et al., 2002). Perhaps, the lack of response in growth performance from ingredient inclusion can likely be explained by the ingredients used within the finishing diet. As the ingredients within the heifer's diet may play a pivotal role in the occurrence or lack of magnitude of the performance results.

Heifers within Exp. 1 received a diet consisting of HMEC, DDGS, and a LS where DDGS and LS varied each day by either -20, -15, -10, -5, 0, +5, +10, +15, or +20% with the daily targeted as-fed amount met by HMEC. As noted from the NASEM 2016 feed library, HMEC has a DM % of (62.54 ± 6.89) with starch (DM %) of (60.16 ± 6.03) and TDN values consisting of (84.3 ± 3.12). Although DDGS and LS may have been altered dramatically, the variation did not substantially change nutrient composition because HMEC providing both an energy and roughage source for those animals. More variation between treatment groups is likely when animals are not provided adequate roughage or energy source.

2.5.2 Carcass Characteristics- Experiment 1

Previous literature data investigating the effects of varying inclusion levels on carcass characteristics of feedlot cattle is limited. In Exp. 1, dietary treatment had no influence on any carcass characteristics to include hot carcass weight, dressing percent, ribeye area, rib fat, marbling, KPH, yield grade, and empty body fat. Lack of response within carcass characteristics was expected as heifers' growth performance and dietary intake showed no differences. Although no differences were detected amongst any carcass characteristics it is worth noting that within this experiment an unexpected amount of liver abscesses was noticed for both CON and VAR. A closer look at the data will be required in order to make a proper conclusion.

2.5.3 Rumination and Activity – Experiment 1

A primary symptom of subclinical acidosis is believed to be decreased and erratic feed intake; that can often be attributed to animals not receiving the correct uniform ration with common associations directed at rapid fermentation of starch within the diet. On the other hand, feeding more meals per day might decrease the likelihood of acidosis by decreasing the amount of starch intake per meal, perhaps creating a more stable rumen environment. However, heifers within Exp. 1 were fed once daily thus receiving large amounts of starch one time each day. In the current experiment there was no treatment effect ($P = 0.70$) on rumination time. In addition, no effect ($P = 0.18$) on animal activity caused by ingredient fluctuations was observed for the duration of the finishing period. This is also consistent with no treatment effect on mean DMI consumed daily during the finishing period.

2.5.4 Animal Growth Performance – Experiment 2

In the present study, varying dietary inclusion did not influence final BW ($P = 0.86$). This agrees with the findings from Exp. 1 where VAR heifers showed no difference in final BW. However, although no significance was noted in final BW for steers. Varying ingredient inclusion accuracy caused greater DMI with similar ADG, resulting in poorer G:F ratios. These results are consistent with the findings reported by Galyean et al. (1992) where a 10% daily variation in feed intake relative to control was imposed. In that experiment the pattern for fluctuating feed intake relative to constant was as follows: 10% greater, equal, 10 less, equal, 10% greater thus making the net intake variation 20% every third interval.

It is possible that, the differing response in DMI between the two experiments were conducted is because of the variable roughage inclusion amount found within each treatment. As CON steers consistently received a 12% roughage inclusion rate for the duration of the finishing period. However, VAR steers who were subject with up to +/- 20% ingredient deviations within ingredients never met a 12% roughage concentration rate. From weeks 7 to 16 when most DMI deviations occurred. VAR steers received on average a diet containing 9% roughage. As it relates to feedlot cattle, increase in roughage within high concentrate diets are well known to prevent digestive upsets and maximize energy (NEg) intake (Galyean and Defoor, 2003). By random alterations of CRNSIL and GH, VAR steers consequently received fluctuations in both roughage and energy sources, resulting in altering both DMI and G:F ratios of VAR. These variations may have altered ruminal pH resulting in sub-clinical digestive upsets reducing apparent dietary net energy for maintenance and grain. That in turn could have been easily masked by slick bunk management.

2.5.5 Carcass Characteristics – Experiment 2

There was a tendency for VAR steers to have greater marbling compared to CON steers within Exp. 2. Previous literature data investigating the effects of varying inclusion levels on carcass characteristics of feedlot cattle is limited. In Exp. 1, dietary treatment had no influence on any carcass characteristics and was largely true for steers fed in Exp. 2. These results are consistent with the carcass characteristics reported by Zinn (1994), in a study evaluating the influence of a 20% variation in daily feed intake on Holstein steers. Variable steers within that study were fed in a cycle of 10% more followed by 10% less than the constant group. Thus, the change in feed intake from day to day was 20%. This variation in daily intake did not affect carcass characteristics. A possible explanation for the tendency for greater marbling in the VAR steers from Exp. 2 was the difference in DMI. As cattle begin to consume more feed later in the finishing period, this energy gets stored in the form of adipose tissue. Although it has long been thought that marbling is a late developing tissue. Bruns (2006) have found that marbling is an intrinsic component of growth throughout an animal's life and often one poor decision within management can have detrimental effects on genetic progress. This can easily be shown within Exp. 2 that although CON steers received a more consistent diet formulation it is possible that due to bunk management cattle may have been limit fed or perhaps not pushed to their near genetic potential like the VAR group.

Although it should be noted that the data showed no treatment effect for QG or YG outcomes within this experiment. A clear economical difference was noted with VAR group having an increased amount of prime graded carcass's resulting in fewer select grades. This outcome is also true for the distribution of yield grade. With the VAR group having an increased amount of yield grade 3 and no yield grade 1 or 5 carcass's. In addition, although not significant the VAR group also had fewer liver abscesses then that of the CON group.

2.6 CONCLUSIONS

In Experiment 1, daily random altering of ingredient proportions by up to 20% did not affect heifer's growth performance, efficiency measures, or carcass characteristics. However, in Experiment 2, applying daily random ingredient variability to crossbred beef steers at a rate of up to 20% showed an increase in DMI by 8.0% in VAR compared to CON. Cumulative ADG showed no difference between CON and VAR treatments resulting in a poorer G:F ratios by 7.1% in CON compared to VAR. These results indicate that randomly altering of daily ingredient proportions that in turn affect roughage inclusion may be detrimental to finishing feedlot cattle performance. Additionally, these results provide further evidence that uniformity within the feedlot is a critical factor for growth performance and health of beef cattle. In particular, Northern Plains cattle feeders could implement to fully optimize production responses in a feedlot setting to improve growth performance during the finishing phase.

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Table 2.1. Experiment 1 – Diet composition (DM basis)[a]

	1 to 112	
	Treatment	
Item	Constant	Variable
Ingredient composition, %		
High Moisture Ear Corn	81.35	74.29
Dried distillers grains	11.82	16.47
Liquid Supplement[b]	6.83	9.24
Nutrient Composition[c]		
Dry matter, %	65.68	67.48
Crude protein, %	13.32	15.45
Neutral detergent fiber, %	21.34	21.90
Acid detergent fiber, %	9.15	9.08
Ash, %	5.25	6.08
EE, %	3.57	3.61
NEm[d], Mcal/kg	2.02	2.03
NEg[e], Mcal/kg	1.38	1.38

[a] All values except dry matter or a DM basis

[b] Liquid supplement: formulated to add 30 g/t of monensin to diet DM and vitamins and minerals or exceed NASEM (2016) requirements.

[c] Tabular NE from (Preston, 2016) and actual nutrient compositions from weekly assay of individual dietary ingredients and feed batching records

[d] Net energy for maintenance

[e] Net energy for gain

Table 2.2. Experiment 2 – Diet composition (DM basis)[a]

	1 to 40		41 to 94[b]	
	Treatment			
Item	Constant	Variable	Constant	Variable
Ingredient composition %				
Dry Rolled Corn, %	22.11	24.86	63.16	67.24
High Moisture Corn, %	49.30	44.19	--	--
Dried distillers grains, %	14.11	15.87	14.95	16.70
Corn Silage, %	--	--	9.94	4.04
Oat Hay, %	11.00	11.64	7.00	7.55
Liquid Supplement[c], %	3.47	3.44	4.95	4.48
Nutrient Composition[d]				
Dry matter, %	76.09	76.87	73.65	81.45
Crude protein, %	14.07	14.59	13.06	13.42
Neutral detergent fiber, %	20.65	21.48	25.45	24.37
Acid detergent fiber, %	11.74	12.38	15.08	14.50
Ash, %	8.28	8.83	5.79	5.41
EE, %	2.84	2.81	2.92	2.92
NEm[e], Mcal/kg	2.00	1.98	1.99	2.02
NEg[f], Mcal/kg	1.39	1.37	1.33	1.35

[a] All values except dry matter or a DM basis
[b] Diet fed for final 53-d of the study when high moisture corn supply was depleted
[c] Liquid supplement: formulated to add 30 g/t of monensin to diet DM and vitamins to meet or exceed NASEM (2016) requirements
[d] Tabular NE from (Preston, 2016) and actual nutrient compositions from weekly assay of individual dietary ingredients and feed batching records
[e] Net energy for maintenance
[f] Net energy for gain

Table 2.3. Experiment 1: Effect of variable inclusion on cattle growth performance.

	Treatment			
Item	Constant	Variable	SEM	*P*-value
Pens, n	5	5	--	--
Steers, n	30	30	--	--
Days on feed	112	112	--	--
Initial body weight (BW), kg	460	461	1.00	0.15
Final Shrunk BW, kg [a]	703	707	8.64	0.70
Carcass-adjusted final BW, kg	670	678	11.8	0.56
Carcass-adjusted Basis				
Average daily gain (ADG), kg	2.18	2.20	0.836	0.56
Dry matter intake (DMI), kg	13.62	13.84	0.548	0.70
ADG/DMI (G:F)	0.151	0.141	0.003	0.96
Observed dietary net energy (NE), Mcal/kg				
Maintenance	2.13	2.13	1.625	0.97
Gain	1.46	1.46	1.426	0.98
Observed-to-expected NE				
Maintenance	1.04	1.04	0.017	1.00
Gain	1.06	1.06	0.023	1.00

[a] Final BW was BW from day 112 that was pencil shrunk 4% to account for gastrointestinal tract fill

Table 2.4. Experiment 2: Effect of variable inclusion on cattle growth performance.

	Treatment			
Item	Constant	Variable	SEM	*P*-value
Pens, n	8	8	--	--
Steers, n	64	64	--	--
Days on feed	94	94	--	--
Initial body weight (BW), kg	506	505	0.95	0.47
Final Shrunk BW, kg[a]	670	671	4.70	0.72
Carcass-adjusted final BW, kg	670	671	5.60	0.86
Carcass-adjusted Basis				
Average daily gain (ADG), kg	1.75	1.76	0.054	0.75
Dry matter intake (DMI), kg	11.53	12.49	0.172	0.01
ADG/DMI (G:F)	0.151	0.141	0.004	0.04
Observed dietary net energy (NE), Mcal/kg				
Maintenance	2.10	2.07	0.615	0.01
Gain	1.44	1.32	0.540	0.01
Observed-to-expected NE				
Maintenance	1.02	0.969	0.009	0.01
Gain	1.02	0.941	0.011	0.01

[a] Final BW was BW from day 94 that was pencil shrunk 4% to account for gastrointestinal tract fill

Table 2.5. Experiment 1: Effect of variable dietary inclusion on heifer carcass and quality characteristics.

	Treatment			
Item	Constant	Variable	SEM	*P*-value
Carcass Traits				
Hot carcass weight, kg	419	424	7.41	0.56
Dressing, %[a]	59.52	59.87	0.27	0.57
Rib fat, cm	1.55	1.63	0.018	0.61
Ribeye area, cm^2	92.58	94.83	0.152	0.35
Marbling score[b]	567	580	9.64	0.55
Calculated yield grade	3.32	3.30	0.048	0.82
Retail Yield, %[c]	49.77	49.86	0.107	0.74
Estimated empty body fat, %[d]	32.02	32.38	0.238	0.53
Final BW at 28% EBF, kg	590	591	14.0	0.94
Quality Dist.				
Select, %	0.0	6.9	-	0.14
Choice, %	86.7	72.4	-	
Prime, %	13.3	20.7	-	
CAB, %	70.0	72.4	-	0.83
Yield Dist.				
2	23.3	31.0	-	0.52
3	60.0	55.2	-	
4	16.7	13.8	-	
Liver abscess prevalence, %				
Normal	63.33	65.52	-	0.84
Abscessed	36.67	34.48	-	

[a] HCW/final BW (shrunk 4%)
[b] 400 = small^{00} (USDA Low Choice)
[c] As a percentage of HCW according to Murphey et al. (1960)
[d] According to Guiroy et al. (2002)

Table 2.6. Experiment 2: Effect of variable dietary inclusion on steer carcass and quality characteristics.

	Treatment			
Item	Constant	Variable	SEM	*P*-value
Carcass Traits				
Hot carcass weight, kg	435	436	3.68	0.87
Dressing, %[a]	65.09	65.01	0.09	0.71
Rib fat, cm	1.75	1.67	0.01	0.38
Ribeye area, cm^2	96.70	97.03	0.10	0.84
Marbling score[b]	510	535	5.59	0.08
KPH, %	2.39	2.38	0.01	0.85
Calculated yield grade	3.54	3.47	0.03	0.38
Estimated empty body fatness, %[c]	32.86	32.86	0.15	0.81
Final BW at 28% EBF, kg	602	604	7.18	0.77
Quality Dist.				
Select, %	15.9	6.9	-	0.51
Low Choice, %	36.5	72.4	-	
Average Choice, %	25.4	20.7	-	
High Choice, %	20.6	72.4	-	
Prime, %	1.6	6.5	-	
Yield Dist.				
1	1.5	0.0	-	0.33
2	26.6	25.0	-	
3	50.0	62.5	-	
4	18.8	12.5	-	
5	3.1	0.0	-	
Liver abscess prevalence, %				
Normal	89.06	96.88	-	0.16
Abscessed	10.94	3.13	-	

[a] HCW/final BW (shrunk 4%)
[b] 400 = $Small^{00}$ (USDA Low Choice)
[c] According to Guiroy et al. (2002)

FIGURE CAPTIONS

Figure 2.1. Experiment 1: Cumulative average rumination time (min) and feeding period (week) during the study (August 28, 2021, to January 15, 2022). It should be noted that week 9 is excluded in data set due to battery issues with accelerometers. (n = 5 pens/treatment; pooled trt × week; SEM = 15.6, *P*-value = 0.63).

Figure 2.2. Experiment 1: Effect of variable dietary inclusion on weekly dry matter intake and pen rumination average in finishing beef heifers. Treatments were: Constant (CON) normal feeding with 0.454 kg tolerance for all ingredients or 2) Variable inclusion strategy where each ingredient was randomly increased or decreased but the targeted as-fed quantity for the daily delivery was met (VAR). Week 9 data not reported due to technology issue with SCR system.

Figure 2.3. Experiment 1: Cumulative average activity level (minutes) and feeding period (week) during the study (August 28, 2021, to January 15, 2022). (n = 5 pens/treatment; pooled trt × week; SEM = 5.4, *P*-value = 0.75).

Figure 2.4. Experiment 1: Cumulative average activity and rumination level (minutes) per feeding period (week).

Figure 2.1. Experiment 1: Cumulative average rumination time (min) and feeding period (week).

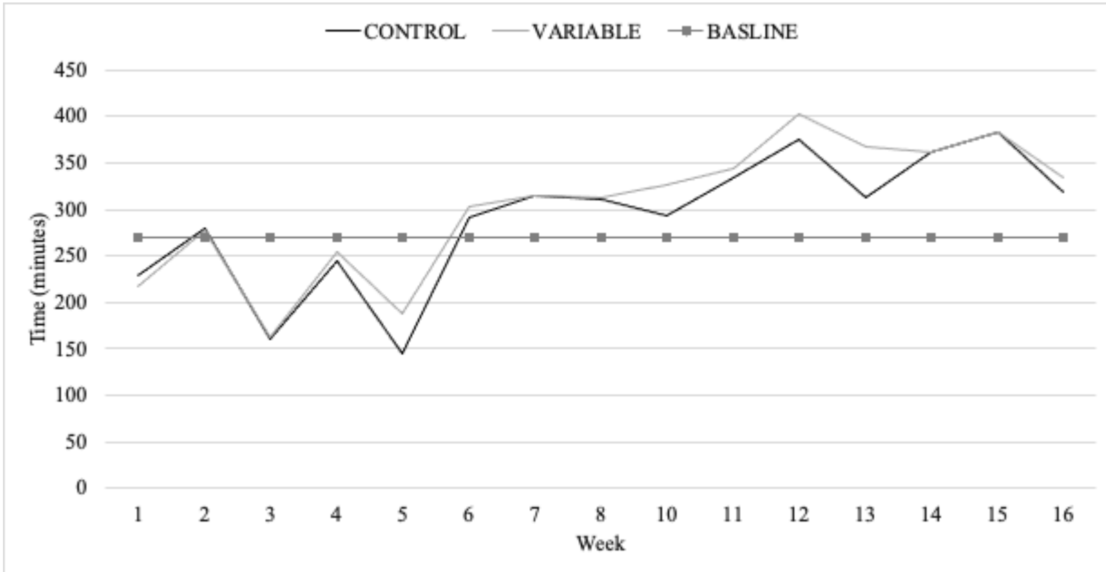

Figure 2.2. Experiment 1: Effect of variable dietary inclusion on dry matter intake (DMI) and weekly pen rumination average in finishing beef heifers.

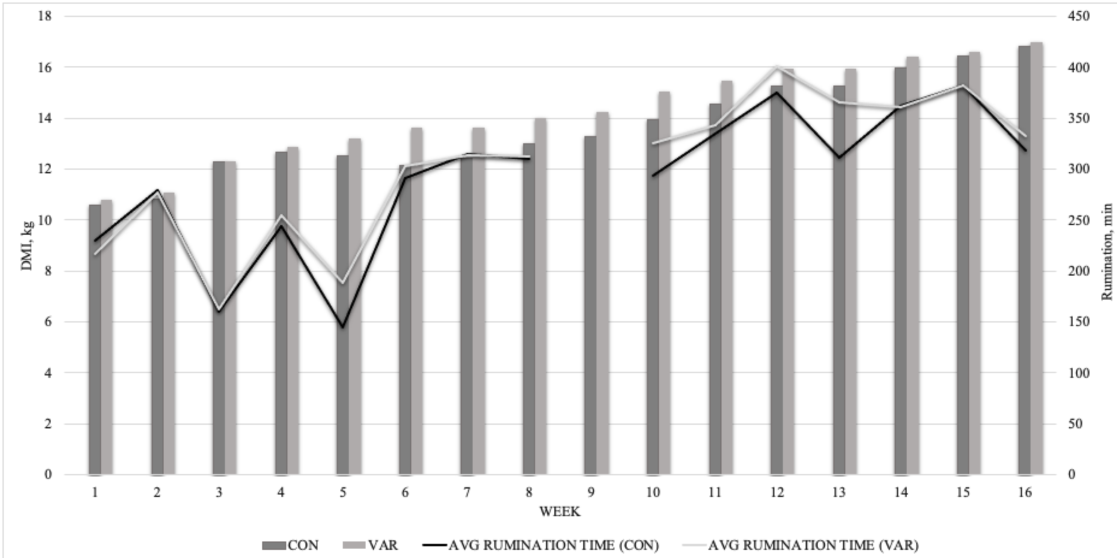

Figure 2.3. Experiment 1: Cumulative average activity level (minutes) and feeding period (week).

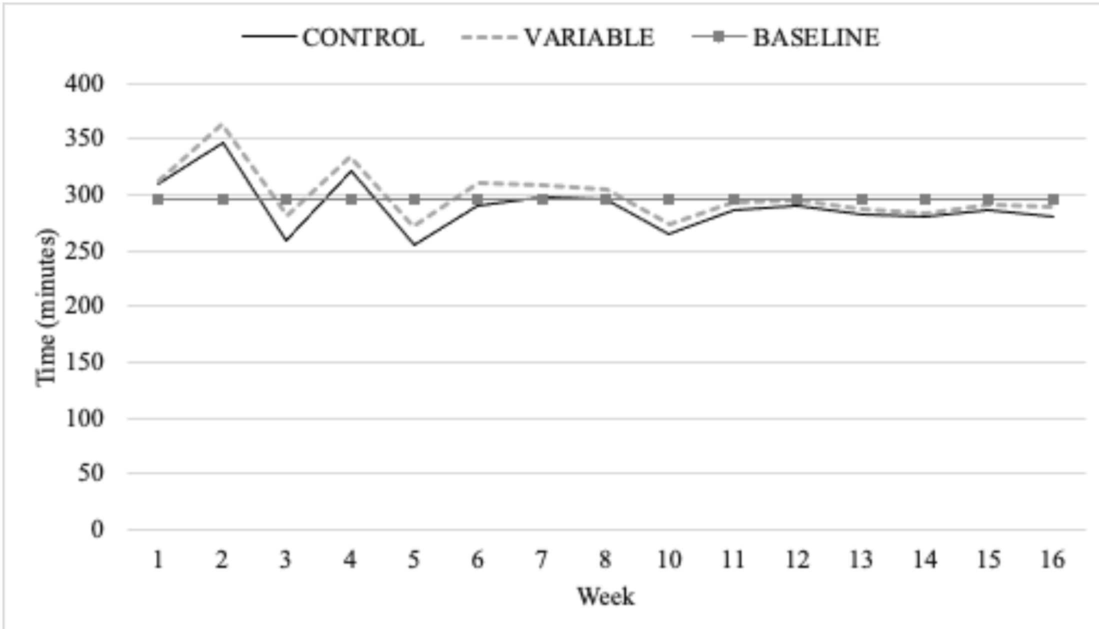

Figure 2.4. Experiment 1: Cumulative average activity and rumination level (minutes) per feeding period (week).