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Corn Grain Alternatives and Coated Versus Non-Coated Trenbolone Acetate and Estradiol Impants for Feedlot Finishing Animals: Influence on Growth Performance, Carcass Characteristics, Efficiency of Dietary Net Energy Utilization, Beef Production per Hectare and Digestiblilty

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CORN GRAIN ALTERNATIVES AND COATED VERSUS NON-COATED TRENBOLONE ACETATE AND ESTRADIOL IMPANTS FOR FEEDLOT FINISHING ANIMALS: INFLUENCE ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, EFFICIENCY OF DIETARY NET ENERGY UTILIZATION, BEEF PRODUCTION PER HECTARE AND DIGESTIBLILTY

BY

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THESIS ACCEPTANCE PAGE

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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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TABLE OF CONTENTS

ABBREVIATIONS

ADF	acid detergent fiber
ADG	average daily gain
AFBW	shrunk weight at 28% empty body fat
BW	body weight
cm	centimeter
CP	crude protein
CS15	corn silage inclusion, 15%
CS30	corn silage inclusion, 30%
d	day
DM	dry matter
DMI	dry matter intake
DRC	dry rolled corn
DP	dressing percentage
E_2	estradiol-17β
EB	estradiol benzoate
EBF	empty body fat
EG	estimated gain

FBW	fasted body weight
FDA	Food and Drug Administration
G:F	gain: feed
g	gram
h	hour
HCW	hot carcass weight
IGF-I	Insulin-like Growth Factor 1
IU	international unit
IMP	implant treatment
kg	kilogram
KPH	kidney pelvic and heart fat
Mcal	megacalorie
mg	milligram
NDF	neutral detergent fiber
NE	net energy
NEg	net energy for gain
NEm	net energy for maintenance
ONE-F	Synovex ONE feedlot, polymer coated implant containing 28 mg estradiol benzoate and 200 mg trenbolone acetate

peNDF	physically effective neutral detergent fiber
PLUS	Synovex PLUS, non-coated implant containing 28 mg estradiol benzoate and 200 mg trenbolone acetate
ppm	parts per million
REA	ribeye area
RF	Rib fat
RNC	Ruminant Nutrition Center
RYE	cereal rye grain
SDSU	South Dakota State University
SEM	standard error of the mean
TBA	trenbolone acetate
17β-TbOH	17β trenbolone
YG	yield grade

LIST OF TABLES

ABSTRACT

CORN GRAIN ALTERNATIVES AND COATED VERSUS NON-COATED TRENBOLONE ACETATE AND ESTRADIOL IMPANTS FOR FEEDLOT FINISHING ANIMALS: INFLUENCE ON GROWTH PERFORMANCE, CARCASS CHARACTERISTICS, EFFICIENCY OF DIETARY NET ENERGY UTILIZATION, BEEF PRODUCTION PER HECTARE AND DIGESTIBLILTY

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Corn grain alternatives are often not used in finishing rations due to reduced caloric densities and reluctance to deviate from traditional methods. Along with optimum nutrition, cattle need to have proper implant strategies to reap maximum returns on investment. Two studies were conducted to evaluate the effects of corn grain alternatives and implant type on feedlot finishing cattle. The objective of the first study was to determine the influence of corn silage (15% or 30% dry matter inclusion), and terminal implant type (coated or non-coated) containing equal hormonal doses on animal growth performance, apparent total tract digestibility, beef production per hectare of cropland, and carcass characteristics in finishing steers harvested at a common rib fat endpoint. The objective of the second study was to determine the effects that complete replacement of dry-rolled corn with unprocessed rye have on dry matter intake (DMI), growth performance, and feed efficiency in finishing beef heifers. In experiment one, 156 Maine-Anjou x Angus cross-bred steers were used with an initial body weight (BW) of 366 ± 37.2 kg. Steers were blocked by weight (n = 5 BW blocks) and randomly assigned to

implant and dietary treatment. Dietary treatments consisted of 1) 15% (CS15) or 2) 30% corn silage (CS30) where corn silage displaced corn grain in the diet. Steers received one of two implants containing equal does of trenbolone acetate (TBA) and estradiol benzoate (EB): 1) Synovex PLUS (non-coated implant; 200 mg TBA and 28 mg EB; Zoetis, Parsippany, NJ; PLUS) or 2) Synovex ONE Feedlot (coated implant; 200 mg TBA and 28 mg EB; Zoetis; ONE-F). There was no interaction between implant and dietary treatment for any variables measured ($P \geq 0.08$). Carcass-adjusted basis final BW, average daily gain (ADG), and gain to feed efficiency (G:F) were increased ($P \leq 0.02$) by 2.2%, 6.5% and 7.2% respectively for CS15. Observed dietary net energy (NE) and the ratio of observed-to-expected NE for maintenance and gain and beef production per hectare were not influenced ($P \geq 0.15$) by silage inclusion treatment. Fecal output was increased, and digestibility coefficients for dry matter, organic matter, and crude protein were decreased in CS30 ($P \leq 0.03$). Dressing percent (DP) and hot carcass weight (HCW) were greater ($P \leq 0.02$) in CS15. Beef production per hectare was not influenced by dietary treatment ($P \geq 0.70$). Implant type did not influence any parameters measured ($P \geq 0.14$) except for marbling being decreased for PLUS (433 vs. 466 ± 17.5; $P = 0.02$) compared to ONE-F steers. Study two used fifty-six heifers (433 ± 34.0 kg) which were blocked by weight grouping and allotted to treatment pens (n = 7 heifers/pen and 4 pens/treatment). Treatments included a finishing diet that contained: 1) Dry-rolled corn as the grain component of the diet (DRC) or 2) contained unprocessed rye as the grain component (RYE). Grain was included at 60% DM inclusion. On d 14 all heifers were consuming the final diet and heifers were implanted with 200 mg trenbolone acetate and 28 mg estradiol benzoate (Synovex-Plus). Heifer from DRC had greater ($P \leq 0.01$) final body weight, ADG, and G:F; however, tended (*P* = 0.08) to have lesser DMI compared to RYE. Heifers from DRC had greater (*P* ≤ 0.01) observed dietary NE for maintenance and gain; heifers from DRC also had a greater (*P* ≤ 0.01) observed-to-expected dietary NE for maintenance and gain compared to RYE. Dressing percentage, 12^{th} rib fat thickness, ribeye area, and the distribution of USDA Yield and Quality grade were not altered (*P* ≥ 0.12) by dietary treatment. Hot carcass weight, calculated yield grade, estimated empty body fatness (EBF), and body weight at 28% EBF were increased (*P* ≤ 0.02) in DRC compared to RYE; and retail yield was decreased (*P* = 0.01) in DRC compared to RYE heifers. This data indicates that un-processed rye is a palatable feed ingredient for inclusion in finishing diets for beef cattle and rye inclusion only minimally influences carcass quality grade. These two studies show that alternatives to corn grain can be fed successfully to finishing beef animals if marketed correctly and with the correct implant regimen. In times of high corn grain prices these feeding methods can be utilized to ensure cattle producers have alternative method to feeding cattle to a desirable market endpoint.

CHAPTER I: REVIEW OF LITERATURE

INTRODUCTION

Corn silage is a widely used feedstuff throughout the upper Midwest in backgrounding cattle and mature cattle diets but typically is only incorporated into finishing rations at a minimum level to maintain ruminal health. Corn silage allows for producers to harvest large quantities of feed quickly along with extend harvesting times over a larger period compared to just the typical corn grain harvest. There are multiple factors that affect corn silage quality such as corn maturity, kernel processing, and stalk processing methods.

Historically corn grain markets are very volatile and unpredictable. Turning to alternative feeds for cattle producers may become crucial as corn grain becomes more expensive. New hybrid types of rye allow for resistance to drought losses in yield along with reduced incidence of ergot. One study of showed promising results in feeding hybrid cereal rye to finishing cattle (Rusche et al., 2020a).

Anabolic implants have proven to be one of the most cost-effective tools producers have to improve cattle performance efficiency and overall net profits. Anabolic implants alter cattle body composition at a common BW in favor of economic benefits such as increased carcass weight. Differences in hormone composition and hormone delivery methods allow producers to tailor implant plans for their specific marketing strategies. By using both alternative feeds and anabolic implants, producers are able to reap optimum profits even during corn price fluctuations.

Corn Silage

Introduction

Corn silage is one of the most prevalent feedstuffs throughout the upper Midwest. There are approximately 51.4 million hectares of cropland with 75% of that being planted with corn and soybeans (USDA, 2017). As feeding the world becomes more challenging it is important to be able to use cropland as efficiently as possible. Utilizing the entire corn stalk for a feedstuff allows producers to harvest more tons of feed per hectare of cropland which could possibly lead to more beef production per hectare (Rusche et al., 2020b). However, by harvesting corn silage this removes corn-stover residues from the field thus, removing more available carbon from the field which could negatively impact soil health. Therefore, it is important to replenish fields with proper fertilization, such as manure. On the other hand, removing more stover from the field allows for non-obstructed emergence of corn the following year. Excessive cornfield residues can cause improper emergence of seeds and reduced seed-to-soil contact (Monsanto, 2018).

Although corn silage is an excellent feedstuff, it can be highly variable in quality and nutritional content. The rule of thumb is that corn silage is 50% grain and 50% roughage. This ratio is highly dependent upon corn maturity. As the corn crop matures the quantity of grain present increases and vice versa (Johnson et al., 1999). Determining the actual ratio of corn grain to roughage is essential for nutritional management before feeding silage. This can be done through neutral detergent fiber (NDF) and acid detergent fiber (ADF) analysis, starch analysis or the less reliable method, floating silage allowing for the corn grain to sink to the bottom and the roughage remain floating then measuring the DM ratio. To use the starch analysis method to determine grain content one must determine the starch content of the grain first. If corn grain is 70% starch (DM basis) and the silage is 35% (DM basis) it can be calculated to predict that the grain content of the corn silage is 50% (DM basis).

The maturity of corn not only effects the ratio of grain to forage but the nutritional content of silage. A common method of measuring the maturity and estimated moisture content of corn grain is done via the milk line assessment. Harvesting corn silage too early leads to decreased grain content and a higher crop moisture content which in return causes seepage from silos, bunkers and piles. Seepage is when moisture from the compacted silage seeps out under the bottom of the silage containment system. This also poses a problem for inventory management because of higher-than-expected shrink. This seepage not only is a problem when it comes to nuisance insects but will also take valuable nutrients along with it. Seepage occurs when moisture levels are above 70% which is also a perfect environment for *clostridia* bacteria to colonize creating butyric acid, carbon dioxide and ammonia thus decreasing corn silage palatability (Tabacco et al., 2009). In the winter, silage that is too wet can cause problems during defacing and is harder to evenly and accurately incorporate into diets. Harvesting corn silage that is too dry promotes mold growth through improper packing of the ensiled mass. Moisture is required for proper compaction within the pile allowing oxygen to be excluded. Ideally, the moisture content of corn silage should be 65% to 68% (Ma et al., 2006).

Kernel processing

Kernel processing of corn silage occurs at the time of corn silage harvest and is one of the fundamental elements that impacts corn silage quality during the feed out phase of production. Kernel processers are rollers installed behind the cutter head that counter rotate each other to crush and pull apart the kernel. The particle size of the kernel determines the surface area available for rumen microbes to attach and start to degrade the starch granules. Particle sizes too large will decrease starch digestion whereas particle sizes too small will cause a surge of starch availability within the rumen; which can be a cause of concern for acidosis. Optimally the kernel should be broken into four pieces. Kernel processing becomes increasingly important as the kernels mature. Mature kernels have a harder pericarp making it harder for rumen microbes to access the endosperm. When scoring kernel processing, kernels that remain above a 4.75 mm screen are not able to be completely fermented in the rumen, negatively impacting growth performance by way of decreased fermentation of starch in the rumen (Drewry et al., 2019).

Stalk processing

It has long been known that cattle require a roughage source even in finishing cattle diets to maintain rumen health and reduce the risk of ruminal acidosis. With corn silage, the stover of the plant acts as an excellent roughage source in diets. Physical length of the corn stover particles determines the physically effective fiber or physically effective neutral detergent fiber (peNDF). Physically effective fiber is considered the fraction of fiber that stimulates chewing activity and the biphasic stratification of the rumen contents. Increased chewing causes an increase in saliva production which contains salivary amylase, bicarbonate (HCO_3^-) and phosphate (HPO_4^{2-}) ions which aid in maintaining proper ruminal pH and digestion (Heinrichs and Kononoff, 2013). Remastication also adds moisture to the chyme along with a decrease in particle size. Physically effective fiber can be estimated using the Penn State Particle Separator. This method uses 3 sieves of varying sizes and a bottom pan. To estimate physically effective fiber the quantity of feed trapped by the top three sieves is added together and multiplied by the NDF content of the feedstuff (Heinrichs and Kononoff, 2013). When analyzing corn silage via the Penn State Particle separator it is suggested that no more than 10% of the sample should be able to pass through to the bottom pan (Heinrichs and Kononoff, 2013). Ideally, peNDF should be estimated by looking at chewing time and running times through an equation to take out individual animal effects; peNDF= [min. of chewing per kg of NDF in the test feed]/[min of chewing per kg of NDF in long grass hay]. This equation determines the proportional change in chewing response which should be consistent among ruminants (Mertens, 2002).

Processing of the corn stover can be done by two different methods, chopping or shredding. Chopping silage too finely decreases the amount of physically effective fiber which in return reduces the quality of the rumen mat, subsequently reducing the amount of tactile stimulation of rumen walls and amount of time cattle spend ruminating each day (Bal et al., 2000). Chop length that is too long leads to issues with storage and feedlot management. Long particles lead to more improper compaction which can, in return, lead to presence of excess oxygen within the pack and result in increased corn silage spoilage that occurs during the feed out phase of corn silage production.

Shredlage is a new process commercialized in 2008 that can be used when harvesting corn silage. This process involves the utilization of corrugated rollers that work in a counter rotational action which grip the corn stover and pull the stalks apart longitudinally. This allows for further separation of the corn stalk beyond conventional chopping. Studies using lactating dairy cattle have shown that when shredlage was incorporated into the diet besides conventionally chopped silage an increase in starch digestibility and DMI was observed. (Ferraretto and Shaver, 2012; Bach et al., 2021). In finishing cattle diets researchers at University of Nebraska-Lincoln saw an increase in final BW, HCW, ADG with lower DMI leading to improved feed efficiency (Conroy et al., 2020).

Corn silage inclusion

As stated before, many cattle producers are reluctant to include more corn silage within finishing diets than what is necessary to maintain rumen health. In a study conducted by Gill et al. (1976) cattle were fed either 14%, 30% or 75% corn silage. Cattle fed the 75% corn silage had to be fed an extra 28 days and exhibited lower carcass weights (310 vs. 324 kg) when compared to the 14% and 30% corn silage fed cattle. The 75% corn silage diets also exhibited lower DP, marbling scores, kidney,-pelvic, and-heart fat, and greater rib fat thickness. This shows that feeding extremely high levels of corn silage, such as 75%, may limit cattle growth efficiency. This may be due to limits on intake because of digestive fill. In another study conducted by Rusche et al. (2020b), it was noted that 24% corn silage inclusion the beef production per hectare was increased when compared to 12% corn silage inclusion. However, they also found a decrease in ADG and G:F for the 24% corn silage which is conducive with the result of the Gill et al. (1976) study. This shows that feeding higher levels of corn silage can be beneficial to the integrated crop livestock producer if inclusion level is below the threshold for limiting DMI.

Beef production per hectare

As the population grows, land available for agriculture diminishes. Between the years of 2016 and 2017 there was a decrease of 2.1 million hectares of harvested agricultural land (USDA, 2019). This trend is predicted to continue therefore it will become increasingly important to be able to increase beef production per hectare of cropland. As stated before, cattle are capable to convert feedstuffs that are not digestible to humans, such as corn stover, and create a highly nutritious protein fit for human consumption. Calculating beef production per hectare can be done by measuring corn silage yields and cross referencing with actual corn silage consumption by cattle and calculating weight gain over the hectares required to feed said cattle.

Overall, not all corn silage is the same. Corn silage composition and processing can highly impact the feeding quality, thus greatly impact cattle performance. For integrated crop, livestock producers increased levels of corn silage within cattle diets may be beneficial for beef production per hectare of cropland and may fit workload demands, and market signals better than harvesting conventional corn grain.

Hybrid Rye

Use of hybrid rye in diversified crops and livestock systems

Increasing crop diversity has proven to increase environmental sustainability due to increased resilience to weather extremes without sacrificing yields (Bowles et al., 2020). Planting only corn or the common corn-soybean rotation is a concern if weather conditions are not favorable for rain. The absence of precipitation has a detrimental effect on corn and soybean yields. For example, in 2012 a drought affected the central US and the corn production was reduced by 25% resulting in $18.6 billion in crop-insurance payouts (Al-Kaisi et al., 2013). Climatologists have projected more frequent and intense heat waves with altered precipitation patterns that would result in increased need for crop-insurance payouts. To prevent this, producers need to look towards more heat and/or drought tolerant alternatives to add in into crop production cycles.

Along with reduced risk of weather-related problems integrating more crop diversity has proven to improve soil health and subsequently improve crop yields. Monocultures of only corn has proven to deplete soils of nitrogen availability and cause an increase in soil erosion. Integrating soybeans has proven to increase nitrogen availability and subsequently increase corn production by approximately 8% (Erickson, 2008), but soybeans offer little benefit in soil erosion. The rotation between corn and soybeans has also proven to decrease pest and disease pressure on crops and increasing the efficiency of both corn and soybean production (Seifert et al., 2017). Diversifying beyond the typical corn-soybean rotation has proven to further increase these rotation benefits. One study showed a 7% increase in corn yields during hot and dry years due to increased rain capture capabilities by the soil when spring cereal grains were planted (Gaudin et al., 2015). Another study has shown a reduction in nitrogen leaching in fields planted with rye before planting corn (Ricks and Fernandez, 2018). This could be contributed to increased rain capture of the soil thus reducing water run-off.

Feeding hybrid rye

Rye is a very versatile feed in the sense that it can be grazed, harvested as forage or allowed to mature and then be harvested as grain and subsequently straw. Feeding cereal rye to cattle has been limited in the past due to the negative effects of ergot ingestion and the subsequent decreases in DMI and at extreme levels, loss of hooves, ear tips, tail-switches and fat necrosis (Matsushima, 2013; Klotz, 2015). Decreases in DMI and productivity are caused by a decrease in passage rate thus causing an increase in ruminal fill but also overall decreases in DM and CP digestibility. The loss of extremities such as the hooves, ear tips, tail switches and fat necrosis is caused by vasoconstriction which leads to damage to blood vessels, edema, and thrombosis. The hybrid rye most commonly planted today has a different germplasm than traditional open-pollinator rye cultivars that is resistant to ergot infestation. With reduced ergot incidence cereal rye becomes a much more favorable feed stuff especially during times of high corn and corn input prices.

Compared to corn grain, rye has a more rapidly fermented starch when present in the rumen. This can be a cause for concern when thinking about ruminal acidosis. That along with the fact that rye is lower in net energy maintenance (NEm) and net energy gain (NEg) makes producers unwilling to feed it. However, as corn prices continue to fluctuate and become more expensive producers may find that rye can be a suitable replacement for corn in finishing cattle. In one study, they found that dry rolled hybrid rye grain mixed with DRC (0.33:0.67; rye:corn) had a positive associative effect possibly due to the differences in starch fermentation within the rumen (Rusche et al., 2020a). The NEm and NEg estimates were 9.5% and 12.8% greater for rye when included in the diet at 20% compared to rye fed at 60% of the diet with no DRC.

In conclusion, hybrid rye grain should not be overlooked as a feedstuff for feedlot finishing cattle. Changes in climate and corn grain markets will lead producers to look for alternative feedstuffs such as rye. Rye also serves as an additional crop diversification species which in turn has soil health benefits. Sustainable agricultural practices will become increasingly important, especially during times of drought.

Steroidal implants with anabolic activity

History

The ability for ruminants to convert poor quality feedstuffs that are indigestible to humans into utilizable protein fit for human consumption is what makes ruminants unique from any other species. From the beginning of growth promoting technology use in the 1950's the goal has been to improve production efficiency, decrease costs and thus improve profitability. This still holds true today and anabolic implants have proven to be one of the best returns on investment technologies cattle producers have at their disposal. There are many forms of implants on the market today such as compressed pellets with or without polymer coatings and rubber delivery vehicles (Reinhardt, 2007). The hormone dosages and combinations vary between brands and the type of cattle the implants are intended to be used. Regardless of implant type they all are known to increase muscle protein deposition while simultaneously decreasing fat at a particular weight (NASEM, 2016). This allows implanted cattle to reach the same body composition at a heavier weight compared to non-implanted cattle (Perry et al., 1991).

Mode of Action

Anabolic hormones can be classified into three groups, androgenic, estrogenic, and progestins. The androgenic hormones marketed for today's feedlot cattle include trenbolone acetate (TBA) and testosterone, with TBA accounting for majority of the androgenic hormones used. The estrogenic compounds include estradiol (E_2), estradiol benzoate (EB) and zeranol. The only progestin compound used is progesterone. All of these hormones, except for TBA, are found naturally in cattle. While TBA is a synthetic molecule which becomes 17β-Trenbolone (17β-TbOH), the active anabolic metabolite, by deacylation within the body (Smith & Johnson, 2020). Implants that contain a combination of androgenic and estrogenic hormones or estrogenic and progestins elicit a greater response than single hormone type implants (Reinhardt, 2007). This is because the three classes of anabolic hormones work in different modes of action. Androgenic hormones work primarily on the muscle, stimulating protein synthesis and reducing muscle catabolism. Estrogenic implants work with the endocrine system to release hepatic somatotropin and insulin-like growth factor 1 (IGF-I). Increased concentrations of IGF-I are crucial for the recruitment of satellite cells needed to support postnatal skeletal muscle hypertrophy. This is a main reason the combination of E_2 and TBA work together for optimal performance of the implant. For any implant to have a biological effect the circulating hormone must reach a threshold. All implants release a greater amount of hormone at the start of the payout period and slowly decrease overtime until they fall below the threshold where growth promotion stops. Coated implants allow for a more extended release of hormones without the harsh spike at the beginning of the payout period so that hormone release stays above the threshold of growth promotion for a longer period.

Hormone delivery throughout a duration of time is key to proper growth. Although the vehicle in which hormones can be delivered differs between implant type, they all have the same concept of slowly allowing hormone release over a specific period of time. With the compressed pellets the inactive carrier degrades allowing for the hormone to be slowly released into the system. Once in blood circulation, the hormones are converted to their biologically active forms and bound to binding globulins and albumin for delivery to target tissues. The biologically active form of the estrogenic compounds is E_2 meaning that EB needs to be converted to E_2 before it can be utilized by the body (approximately 73% conversion of EB to E_2). Some pellets now come with a polymer coating which degrades over time to expose the active pellets. This coating allows for extended hormone release beyond the typical payout duration of non-coated pellets. Companies have created implants with some of the pellets coated and the others non-coated. The non-coated implant pellets and the polymer coating degrade at the same rate meaning, the remaining pellets are available for hormone release as the first ones are used. This allows for cattle to not require reimplantation thus reducing labor costs, risk of cattle injury, and implant rejection. The problem with one implant protocols is that cattle that reject implantation will most likely not be reimplanted with a secondary implant. Therefore, it is important to have a highly trained implantation team and conduct implant retention checks to ensure that the majority of cattle are retaining implants. Another consideration for the difference between coated and non-coated implants is the spike in circulating hormone at the beginning of the payout period. Coated implants require degradation of the polymer coating to release the anabolic hormones, thus causing a more gradual release of hormones at the start of the payout period. This is important for cattle that are still increasing DMI upon arrival to the feedlot and when cattle are marketed on a quality grade-based grid. Increasing the caloric demand for lean muscle growth will divert caloric intake away from intramuscular fat deposition subsequently hindering USDA quality grade at the time of harvest. Many studies have proven that a polymer coating of implants reduces the risk of decreased quality grades due to implantation (Smith et al. 2018, Parr et al. 2014).

Growth performance

Improving feed efficiency and the carcass characteristics of feedlot cattle is of utmost importance to the beef industry. Implants have proven to be a vital tool in improving the efficiency of cattle production. Depending upon stage of production, implants have proven to increase average daily gain by 8% to 28% and feed efficiency by 5% to 20% when compared to non-implanted cattle (Johnson & Beckett, 2014; Smith, 2018; Johnson et al., 1996). A 40 to 50 kg increase in mature body weight is what is generally observed by implanted cattle compared to non-implanted cattle (Parr et al. 2014, Smith and Johnson, 2020, Preston et al. 1990). Implants not only alter efficiency of growth but increase frame size and delay the onset of fattening. This ultimately alters the days required to be on feed and increases final shrunk body weight due to cattle being larger at time of harvest to reach a common body compositional endpoint compared to non-implanted cattle. Many factors play into effect of the performance response such as cattle type, cattle sex, implant type, hormone dosage, and management practices. Cattle that are genetically pre-disposed to greater growth performance efficiency will see a greater numerical (absolute) increase in growth performance compared to cattle that are genetically pre-disposed to non-favorable growth performance. Implants have been tailored to fit specific groups of cattle based upon their stage of production and sex. Typically steer implants have greater levels of estrogen-based hormones compared to heifer implants (PBSHealth, 2019). Management is also a large deciding factor on the growth performance responses observed by cattle. Cattle that have had time to intake adequate nutrition upon arrival to the feedlot will exhibit greater growth performance efficiency compared to cattle that have not received adequate nutrition. Nutritional management is also crucial for growth efficiency of implanted cattle. Properly matching nutritional requirements to implant regimens will increase growth efficiency observed.

Carcass characteristic effects

One concern for anabolic implants on carcass quality is a reduction in marbling score. As stated before, anabolic implants delay fat deposition in cattle. When implant strategies are not properly matched with nutritional plans cattle can see a reduction in marbling scores at the time of harvest. This is due to inadequate calories compared to growth rates at time of implant payout initiation. Marbling has been proven to be linear function of growth, therefore when calories are diverted away from intramuscular fat depositions and put towards lean muscle growth it is hard to recover intramuscular fat accumulation (Bruns et al., 2004). Therefore, it is important to ensure cattle are consuming an adequate quantity of food before administering any anabolic implant.

Anabolic implants are a vital tool for cattle producers due to the increase in cattle efficiency and the increased body weight at time of harvest. When choosing an implant type many factors should be considered including cattle type, sex, management practices, and nutritional plans. Concerns of decreased qualities grades should be met with proper pairing of nutrition, management, marketing and implant protocols.

Conclusion to Literature Review

In conclusion, corn silage will remain one of the most important feedstuffs throughout the upper Midwest. Corn silage quality examination is needed to feed cattle with precision. This can be done by analyzing corn silage maturity, roughage to grain ratio, moisture content, kernel processing quality, and stalk processing. Hybrid rye shows promising results in feeding feedlot finishing cattle. During volatile corn markets and evolving climate change and weather patterns, it will be necessary for cattle producers to turn to alternative feedstuffs other than conventional corn grain or corn-soybean rotation. Anabolic implants are one of the most important tools producers have for improving cattle performance and growth efficiency. Anabolic implant technology is constantly evolving to help producers tailor their implant strategies to match their cattle marketing plans. The use of alternative feedstuffs and anabolic implants will help producers improve net profits and protect producers against volatile grain market prices and changing climate.

LITERATURE CITED

Al-Kaisi, M. M., R. W. Elmore, J. G. Guzman, H. M. Hanna, C. E. Hart, M. J. Helmers, E. W. Hodgson, A. W. Lenssen, A. P. Mallarino, and A. E. Robertson. 2013. Drought impact on crop production and the soil environment: 2012 experiences from Iowa. Journal of Soil and Water Conservation 68(1):19A-24A.

Bach, A., I. Joulie, E. Chevaux, G. Elcoso, and J. Ragués. 2021. Milk performance and rumen microbiome of dairy cows as affected by the inclusion of corn silage or corn shredlage in a total mixed ration. Animal 15(1):100014. doi: https://doi.org/10.1016/j.animal.2020.100014

Bal, M. A., R. D. Shaver, A. G. Jirovec, K. J. Shinners, and J. G. Coors. 2000. Crop Processing and Chop Length of Corn Silage: Effects on Intake, Digestion, and Milk Production by Dairy Cows. Journal of Dairy Science 83(6):1264-1273. doi: https://doi.org/10.3168/jds.S0022-0302(00)74993-9

Bowles, T. M., M. Mooshammer, Y. Socolar, F. Calderón, M. A. Cavigelli, S. W. Culman, W. Deen, C. F. Drury, A. Garcia y Garcia, A. C. M. Gaudin, W. S. Harkcom, R. M. Lehman, S. L. Osborne, G. P. Robertson, J. Salerno, M. R. Schmer, J. Strock, and A. S. Grandy. 2020. Long-Term Evidence Shows that Crop-Rotation Diversification Increases Agricultural Resilience to Adverse Growing Conditions in North America. One Earth 2(3):284-293. doi: https://doi.org/10.1016/j.oneear.2020.02.007

Bruns, K. W., R. H. Pritchard, and D. L. Boggs. 2004. The relationships among body weight, body composition, and intramuscular fat content in steers1. Journal of Animal Science 82(5):1315-1322. doi: 10.2527/2004.8251315x

Conroy, B., M. Jaynes, R. Pritchard, and K. H. Jenkins. 2020. Comparing SHREDLAGE® and Conventional Silage as a Roughage Component in Steam-Flaked Corn Diets for Finishing Cattle. 2020 Nebraska Beef Cattle Report p. 89-90.

Drewry, J. L., B. D. Luck, R. M. Willett, E. M. C. Rocha, and J. D. Harmon. 2019. Predicting kernel processing score of harvested and processed corn silage via image processing techniques. Computers and Electronics in Agriculture 160:144-152. doi: https://doi.org/10.1016/j.compag.2019.03.020

Erickson, B. 2008. Corn/soybean rotation literature summary. Purdue Univ., West Lafayetter, IN

Ferraretto, L. F., and R. D. Shaver. 2012. Effect of Corn Shredlage on lactation performance and total tract starch digestibility by dairy cows. The Professional Animal Scientist 28(6):639-647. doi: https://doi.org/10.15232/S1080-7446(15)30423-X

Gaudin, A. C., T. N. Tolhurst, A. P. Ker, K. Janovicek, C. Tortora, R. C. Martin, and W. Deen. 2015. Increasing crop diversity mitigates weather variations and improves yield stability. PloS one 10(2):e0113261. https://doi.org//10.1371/journal.pone.0113261.

Gill, D. R., J. R. Martin, and R. Lake. 1976. High, Medium and Low Corn Silage Diets with and without Monensin for Feedlot Steers. Journal of Animal Science 43(2):363-368. doi: 10.2527/jas1976.432363x

Heinrichs, J., and P. Kononoff. 2013. The Penn state particle separator. Penn State Extension, University Park, PA. DSE 186:1-8.

Johnson, B., P. Anderson, J. Meiske, and W. R. Dayton. 1996. Effect of a combined trenbolone acetate and estradiol implant on feedlot performance, carcass characteristics, and carcass composition of feedlot steers. Journal of Animal Science 74(2):363-371.

Johnson B.J., and J. Beckett. 2014. Application of growth enhancing compounds in modern beef production executive summary. American Meat Association Reference Paper For 2014:1–15.

Johnson, L., J. H. Harrison, C. Hunt, K. Shinners, C. G. Doggett, and D. Sapienza. 1999. Nutritive Value of Corn Silage as Affected by Maturity and Mechanical Processing: A Contemporary Review. Journal of Dairy Science 82(12):2813-2825. doi: https://doi.org/10.3168/jds.S0022-0302(99)75540-2

Klotz, J. L. 2015. Activities and Effects of Ergot Alkaloids on Livestock Physiology and Production. Toxins 7(8):2801-2821.

Ma, B., K. Subedi, D. Stewart, and L. Dwyer. 2006. Dry matter accumulation and silage moisture changes after silking in leafy and dual-purpose corn hybrids. Agronomy Journal 98(4):922-929.

Matsushima, J. K. 2013. Feeding beef cattle. Springer Science & Business Media.

Mertens, D. R., 2002. Measuring fiber and its effectiveness in ruminant diets. Plains Nutrition Council

Monsanto. 2018. Corn-on-Corn Management Guide. https://www.corn-states.com/app/uploads/2018/07/Corn-on-Corn-Management-Guide.pdf

National Academies of Sciences, E., and Medicine. 2016. Nutrient requirements of beef cattle. National Academies Press.

Parr, S., T. Brown, F. Ribeiro, K. Chung, J. Hutcheson, B. Blackwell, P. Smith, and B. Johnson. 2014. Biological responses of beef steers to steroidal implants and zilpaterol hydrochloride. Journal of animal science 92(8):3348-3363.

PBS Health. 2019. Cattle Implant Comparison Chart. https://www.pbsanimalhealth.com/media/W1siZiIsIjIwMTkvMDMvMTgvMTUvMTMvMzMvODRjMDhkMmItM2RlZS00ZjhjLWEzODAtOWRjMGQ0ZWRkY2JmL0NhdHRsZUltcGxhbnRDb21wYXJpc29uQ2hhcnQucGRmIl1d/CattleImplantComparisonChart.pdf?sha=c527236e45d2f9de

Perry, T. C., D. G. Fox, and D. H. Beermann. 1991. Effect of an implant of trenbolone acetate and estradiol on growth, feed efficiency, and carcass composition of Holstein and beef steers. J Anim Sci 69(12):4696-4702. doi: 10.2527/1991.69124696x

Preston, R., S. Bartle, A. Brake, and R. Castlebury. 1990. Effect of anabolic growth implants on the time required to reach quality grade equivalent to nonimplanted cattle. Agricultural Sciences Technical Report No. T-5–283.

Reinhardt, C. 2007. Growth-Promotant Implants: Managing the Tools. Veterinary Clinics of North America: Food Animal Practice 23(2):309-319. doi: https://doi.org/10.1016/j.cvfa.2007.03.004

Ricks, N. and F. Fernandez. 2018. Rye Cover Crops in Corn Produciton on Irrigated Sands. Minnesota Crop News. https://blog-crop-news.extension.umn.edu/2018/01/rye-cover-crops-in-corn-production-on.html

Rusche, W. C., J. A. Walker, P. Sexton, R. S. Brattain, and Z. K. Smith. 2020a. Evaluation of hybrid rye on growth performance, carcass traits, and efficiency of net energy utilization in finishing steers. Translational Animal Science 4(3): 1-10. doi: 10.1093/tas/txaa173

Rusche, W. C., J. A. Walker, and Z. K. Smith. 2020b. Effect of inclusion rate of silage with or without alpha-amylase trait on finishing steer growth performance, carcass characteristics, and agronomic efficiency measures. Translational Animal Science 4(2):942-949. doi: 10.1093/tas/txaa056

Seifert, C. A., M. J. Roberts, and D. B. Lobell. 2017. Continuous corn and soybean yield penalties across hundreds of thousands of fields. Agronomy Journal 109(2):541-548.

Smith, Z. K., A. J. Thompson, J. P. Hutcheson, W. T. Nichols, and B. J. Johnson. 2018. Evaluation of coated steroidal implants containing trenbolone acetate and estradiol-17β on live performance, carcass traits, and sera metabolites in finishing dfv grdes, and G. Borreani. 2009. Clostridia spore formation during aerobic deterioration of maize and sorghum silages as influenced by Lactobacillus buchneri and Lactobacillus plantarum inoculants. Journal of applied microbiology 107(5):1632-1641

Smith, Z. K., and B. J. Johnson. 2020. Mechanisms of steroidal implants to improve beef cattle growth: a review. Journal of Applied Animal Research 48(1):133-141. doi: 10.1080/09712119.2020.1751642

Tabacco, E., S. Piano, L. Cavallarin, T. Bernardes, and G. Borreani. 2009. Clostridia spore formation during aerobic deterioration of maize and sorghum silages as influenced by Lactobacillus buchneri and Lactobacillus plantarum inoculants. Journal of applied microbiology 107(5):1632-1641.

USDA. 2017. Agriculture in the midwest, USDA Washington DC.

USDA. 2019. Crop Production Summary - 2018 summary

CHAPTER TWO:

EFFECTS OF CORN SILAGE INCLUSION LEVEL AND TYPE OF ANABOLIC IMPLANT ON ANIMAL GROWTH PERFORMANCE, APPARENT TOTAL TRACT DIGESTIBILITY, BEEF PRODUCTION PER HECTARE, AND CARCASS CHARACTERISTICS OF FINISHING STEERS

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ABSTRACT

Maine-Anjou × Angus cross-bred steers (*n* = 156 steers; initial body weight (BW) 366 ± 37.2 kg) were used in a 132 d finishing study conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD. Steers were blocked by weight (*n* = 5 BW blocks) and randomly assigned to an implant and dietary treatment of a randomized complete block design with each pen containing seven to eight steers (*n* = 20 pens). Dietary treatments consisted of (1) 15% (CS15) or (2) 30% corn silage (CS30) where corn silage displaced corn grain in the diet. Steers received one of two implants (both from Zoetis, Parsippany, NJ) containing equal doses of trenbolone acetate (TBA) and estradiol benzoate (EB): (1) Synovex PLUS (non-coated implant; 200 mg TBA and 28 mg EB; PLUS) or (2) Synovex ONE Feedlot (coated implant; 200 mg TBA and 28 mg EB; ONE-F). Bunks were managed using a slick bunk approach, and all diets contained dry matter (DM) basis 33 mg/kg monensin sodium. All steers were offered *ad libitum* access to feed, and feeding occurred twice daily in equal portions. There was no interaction between the implant and dietary treatment for any variables measured ($p \geq 0.08$). Carcass-adjusted basis final BW, average daily gain (ADG), and grain to feed (G:F) were increased ($p \leq 0.02$) by 2.2%, 6.5%, and 7.2%, respectively, for CS15. Observed net energy (NE) and the ratio of observed-to-expected NE for maintenance and gain was not influenced ($p \geq 0.15$) by silage inclusion treatment. Beef production per hectare was not impacted ($p \geq 0.13$) by corn silage inclusion level. Fecal output was increased, and digestibility coefficients for dry matter, organic matter, and crude protein were decreased in CS30 ($p \leq 0.03$). Dressing percent and hot carcass weight (HCW) were greater ($p \leq 0.02$) in CS15. Implant type did not influence any traits measured ($p \geq 0.14$) except for marbling. Marbling was

decreased for PLUS (433 vs. 466 ± 17.5; $p = 0.02$) compared to ONE-F steers. Similar beef produced per hectare of crop land-based upon silage feeding level means producers can feed greater inclusions of corn silage to finishing cattle without impacting carcass quality or beef production; implanting with a coated implant had no detrimental effects to growth performance but increases marbling scores.

INTRODUCTION

Corn silage is a staple feed ingredient among Midwestern cattle producers. The most recently conducted Feedlot Consulting Nutritionist Survey indicated that corn silage was the primary (37.5% of respondents) and secondary (37.5% of respondents) roughage source used in finishing diets (Samuelson et al., 2016). Corn silage production allows farmers to maximize feed tonnage per hectare of land and harvest the crop at an earlier time compared to corn grain. Additionally, adequate amounts of corn silage needed for annual roughage needs can be harvested in shorter time period compared to other roughage source crops that require multiple cuttings to attain adequate roughage inventory. This difference in harvest time also allows for flexibility of harvest due to weather conditions, labor availability, and corn market prices (Goodrich et al., 1974; DiCostanzo et al., 1997). However, a long-held belief among cattle producers is that corn silage is best suited for growing cattle and should only be included in finishing rations to maintain optimal ruminal health (Samuelson et al., 2016). Most of the prevailing research conducted on corn silage inclusion rates in finishing cattle diets evaluate gain to feed on an animal basis, but few have evaluated corn silage inclusion in terms of beef production per hectare of cropland. Since land is the limiting factor on production capabilities for most integrated crop-livestock systems, this aspect of efficiency from a fixed land asset base is extremely important for integrated crop-livestock producers. Previous research conducted by this research group suggests that for integrated crop-livestock production systems increased corn silage inclusion in finishing beef diets has no detrimental effect to beef produced per hectare of cropland (Rusche et al., 2020).

Steroidal hormones with anabolic activity have been safely used by the U.S. beef production industry since 1956 (Smith and Johnson, 2020). Implants delay fattening, increase frame size and increase protein accretion which allows for increased beef production (Johnson et al., 1996). For over 28 years anabolic implants containing trenbolone acetate (TBA) and estradiol-17β (E_2) and modified forms of estradiol such as estradiol benzoate (EB) have been approved for use in confined finishing cattle by the United States Food and Drug Administration (FDA) (Smith et al., 2020b; Smith and Johnson, 2020). For extended hormonal release periods of up to 200 d post-implantation the FDA has approved coated TBA and estradiol based steroidal implants.

The objective of this experiment was to determine the effect corn silage inclusion level and terminal implant type (coated or non-coated) containing equal hormonal doses has on animal growth performance, apparent total tract digestibility, beef production per hectare of cropland, and carcass characteristics in finishing steers harvested at a common rib fat endpoint.

MATERIALS AND METHODS

Animal care and handling procedures used in this study were approved by the South Dakota State University Animal Care and Use Committee (Approval Number: 19-026E).

Animal management, dietary and implant treatments

Maine-Anjou × Angus beef steers were used to evaluate the effects of increased inclusion rates of corn silage and the effects of coated or non-coated steroidal implants on growth performance, dietary NE utilization, apparent total tract digestibility, beef produced per hectare, and carcass traits. One-hundred and fifty-six steers (BW 366 ± 37.2 kg) were selected from an original pool of one-hundred and ninety-nine steers based upon uniformity. These steers were procured from an unrelated receiving and growing phase study conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD. Approximately 90 d prior to the initiation of the present experiment all steers were vaccinated for viral respiratory pathogens (Bovashield Gold 5, Zoetis, Parsippany, NJ) , clostridia species (Ultraback 7/Sombac, Zoetis, Parsippany, NJ), and treated for internal and external parasites with topical moxidectin (Cydectin, Bayer Healthcare, Shawnee Mission, KS) . Steers were housed in a 7.62 m × 7.62 m concrete surface pen with 7 to 8 steers per pen. Steers were individually weighed (scale readability of 0.454 kg) on two consecutive days and blocked by BW grouping (n = 5 BW blocks). Once assigned to block, steers were assigned to dietary treatment and implant type. Treatment diets were: 1) 15% (CS15) or 2) 30% DM inclusion of corn silage (CS30). Implant treatment were: 1) Synovex PLUS (non-coated implant; 200 mg TBA and 28 mg EB; Zoetis, Parsippany, NJ; PLUS) or 2) Synovex ONE Feedlot (coated implant; 200 mg TBA and 28 mg EB;

Zoetis; ONE-F). Feed bunks were managed using a slick bunk approach and all diets contained (DM basis) 33 mg/kg monensin sodium. Fresh feed was manufactured twice daily in a stationary mixer (2.35 m^3; scale readability of 0.454 kg) and offered to steers in equal parts at each feeding (07:00 and 14:00 h). Orts were collected, weighed, and dried in a forced air oven at 60 ˚C for 24 hours if feed became out of condition or prior to weigh days if present. Dry matter intake (DMI) was determined by subtracting the dried orts from the total dry matter (DM) delivered to each pen. Actual diet formulation (Table 2.1) was based upon weekly DM analysis (drying at 60 ˚C until no weight change was observed) and corresponding feed batching records. After weekly DM, proximate analysis of each ingredient (except for liquid supplement) was conducted weekly according to: DM [method no. 935.29; (AOAC, 2012)], N [method no. 968.06; (AOAC, 2016); Rapid Max N Exceed; Elementar; Mt. Laurel, NJ] where crude protein (CP) was determined form N × 6.25, and ash [method no. 942.05; (AOAC, 2012)]. Tabular ether extract values for all ingredients were used (NASEM, 2016). Percentages of ADF and NDF were assumed to be 3 and 9% for corn, respectively. Analysis of ADF and NDF composition for all other ingredients was conducted as described by (Goering & Van Soest, 1970).

Steers were given a clostridium type A vaccination (Clostridium Perfringens Type A Toxoid for Cattle, Elanco, Indianapolis, IN) and implant retention was checked on d 28. Implant status was checked by a single trained evaluator, abnormal implant rate was 12.2%; abnormalities included abscess (1 steer), abscessed out (1 steer), hard (1 steer), partial (3 steers) and soft inflammation (12 steers). Severe abnormalities such as abscess or abscessed out only occurred in 1.3% of the population. The missing implant was re-administered the treatment implant on trial day 28.

Growth performance calculations

Steers were individually weighed on d -1, 1, 28, 56, 84, 112 and 132. Live basis cumulative growth performance was based upon the initial and final shrunk BW (4% shrink was applied to account for digestive tract fill) and carcass-adjusted based growth performance was based upon initial shrunk BW and carcass-adjusted final BW (FBW; HCW/0.63). Average daily gain (ADG) was calculated by the difference in BW during the period of interest, divided by the number of days within the period. The gain to feed (G:F) ratio was calculated by ADG/DMI.

Efficiency of dietary NE utilization calculations

Observed dietary NE was calculated using live shrunk-basis growth performance, and from daily energy gain (EG; Mcal/d): EG = $ADG^{1.097} \times 0.0557W^{0.75}$, where W is the mean equivalent shrunk BW (kg; median feeding BW × 478/Mature final BW (National Academies of Sciences & Medicine, 2016)) based upon median feeding weight (average of live basis initial and final shrunk BW). Mature final body weight was the final BW at 28% empty body fat (EBF) (Guiroyet al., 2001; National Academies of Sciences & Medicine, 2016). Maintenance energy (EM) was calculated using the equation: EM = 0.077 (median feeding BW, $kg^{0.75}$). Dry matter intake is related to energy requirements and dietary NEm according to the following equation: DMI = EG/(0.877NEm – 0.41), and can be resolved for estimation of dietary NEm by means of the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$ where a = -0.41EM, b = 0.877EM + 0.41DMI + EG, and c = -0.877DMI

(Zinn & Shen, 1998). Dietary NEg was derived from NEm by the following equation: NEg = 0.877NEm – 0.41 (Zinn, 1987).

Beef production per hectare calculations

The beef production per hectare of cropland was calculated from actual intake of corn silage and corn grain (dry-rolled- and high-moisture corn) for each pen. Weekly diet compositions and DMI records were used in these calculations. Corn silage yield was assumed to be 45.7 Mg/ha and corn grain yield was calculated to be 10.2 Mg/ha. Beef production per hectare was calculated as: (final BW – initial BW)/hectare.

Apparent total tract digestibility sampling and analysis

Approximately three weeks prior to harvest apparent total tract digestibility of diet DM, organic matter (OM), and CP was determined using an internal marker ratio technique. Feed samples were collected from the morning and afternoon feedings starting two days prior to fecal collections. Samples were compiled in equal amounts from each feeding to create a single composite sample of feed for each pen. Fecal samples were taken via rectal palpation at 07:30 h and again at 14:30 h on d 2 of feed collection. Feed and fecal samples were dried and ground through a 1-mm sieve after oven drying at 60 ˚C until no weight change was observed. Acid insoluble ash was used as an internal marker (Van Soest et al., 1991). Digestibility was calculated using the marker ratio equation: 100 - 100 × (feed marker/fecal marker) × (fecal variable/feed variable). After DM determination (method no. 935.29; (AOAC, 2012)), composite samples were analyzed for N (method no. 968.06;(AOAC, 2016)) then N was multiplied by 6.25 to determine CP and placed in a muffle furnace for 12 hours at 500 ˚C for OM determination. One pen was removed from the analysis to irregular digestibility coefficients that fell more than three standard deviations away from the overall mean for all parameters.

Carcass trait determination

Steers were harvested when visually appraised to 1.02 cm of rib fat (RF). Cattle were transported to Iowa Premium Beef in Tama, IA after 132 d on feed and harvested the following day. Steers were co-mingled at the time of shipping and remained so until 07:00 h the morning of harvest. Steers were tracked throughout the harvest facility by trained personnel. Hot carcass weight was recorded at the hot scale during the tag transfer procedure. Trained personnel at the packing plant obtained the carcass trait data such as rib eye area (REA), RF, and USDA marbling scores. Dressing percentage (DP) was calculated as: HCW/ (Final BW × 0.96). Yield grade was determined using the United States Department of Agriculture (USDA) regression equation (USDA, 1997). Estimated empty body fat (EBF) percentage and final BW at 28% EBF (AFBW) were calculated from observed carcass traits (Guiroy et al., 2002), and proportion of closely trimmed boneless retail cuts from the chuck, loin, rib and round as a percentage of HCW (retail yield, RY; (Murphey et al., 1960)).

Statistical analysis

Deads and removals were excluded from all statistical analysis. Growth performance, beef production per hectare, carcass traits, efficiency of dietary NE utilization, and apparent total tract digestibility were all analyzed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC). For all analysis, the model included the fixed effects of steroidal implant, corn silage inclusion level, and their interaction; block was considered a random effect. Least square means were generated using the LSMEANS statement of SAS. Data means were separated and denoted to be different using the pairwise comparison PDIFF and LINES option of SAS when a significant preliminary F-test was detected. An α of 0.05 determined significance and tendencies are discussed from 0.05 to 0.10. One pen was removed from the statistical analysis of digestibility due to all values being greater than three standard deviations away from the mean.

RESULTS AND DISCUSSION

Cumulative growth performance

Growth performance responses are located in Table 2.2. There was no interaction of silage × implant ($P \geq 0.22$) for any growth performance measures. Silage inclusion level did not influence live-basis final BW, ADG, or G:F ($P \geq 0.19$). Carcass adjusted final BW, ADG, and G:F were increased ($P \leq 0.02$) by 2.2%, 6.5% and 7.2% respectively for CS15 compared to CS30. Discrepancies amongst live- and carcass-adjusted basis growth performance was due to differences in digestive fill and DP that could not be accounted for in common pencil shrink that was applied for live-basis shrunk growth performance. The main effect of terminal implant type did not influence ($P \geq 0.54$) any live- or carcass-adjusted growth performance parameters. Others have indicated that feeding greater levels of corn silage to finishing steers did not influence growth performance (Warren et al., 2020). However, it has been noted that coated versus non-coated implants differentially affect growth performance (Cleale et al., 2012; Smith et al., 2019b).

Tabular ingredient energy values were in close agreement with cattle performance (Table 2.2). No interaction of silage × implant ($P \geq 0.85$) or the main effects of silage ($P \geq 0.15$) or implant ($P \geq 0.90$) were detected for observed dietary NE based upon performance or the ratio of observed-to-expected dietary NE in the present study. This is consistent with what has been reported by others when greater levels of corn silage is fed to finishing steers (Rusche et al., 2020). While data comparing efficiency of dietary NE utilization between coated and non-coated implants is limited.

Beef production per hectare

No interaction of silage × implant ($P \geq 0.70$) or the main effects of silage ($P \geq 0.13$) or implant ($P \geq 0.56$) were detected for agronomic returns (live basis or carcass-adjusted basis beef produced per hectare of cropland). Numerical differences in live-basis versus carcass-adjusted basis agronomic returns is likely due to the same reasons related to applying a generic pencil shrink to diets differing in NDF content and harvesting steers at an equal duration of days on feed. This study does demonstrate that producers can effectively feed higher levels of corn silage with no detrimental effects to beef produced per hectare, which is similar to Smith and Johnson, 2020. Additionally, implant type used does not influence agronomic returns to a fixed land base.

Apparent total tract digestibility

Apparent total tract digestibility parameters are presented in Table 2.3. No silage × implant interaction was detected for any measurements ($P \geq 0.08$). Intake did not differ between silage group (*P* = 0.41) or implant (*P* = 0.16) during the apparent total tract digestibility measurement period. Fecal output was increased 36.9% (*P* = 0.01) in CS30 compared to CS15. Digestibility coefficients for DM, OM, and CP were decreased ($P \leq 0.03$) with increased level of silage but were not influenced ($P \geq 0.20$) by steroidal implant type.

Carcass traits

Carcass trait responses are located in Table 2.4. No interaction of silage × implant was detected for any carcass trait parameters ($P \geq 0.16$). The inclusion level of silage had no effect on REA, RF, USDA marbling score, calculated yield grade, retail yield, estimated EBF, final BW at 28% EBF, or the distribution of USDA Quality or Yield grades. Dressing percentage was increased for CS15 (64.52 vs. 63.47 ± 0.250; *P* = 0.01) which can be attributed to decreased digestive fill compared to the CS30 diet. With cattle finishing at a similar final body weight (588 vs. 585 kg; *P* = 0.62) with differing DP it was to no surprise the HCW was greater in CS15 (379 vs. 371 ± 13.1 kg; *P* = 0.02).

When comparing implant treatments, no differences were observed for dressing percent, hot carcass weight, ribeye area, or rib fat ($P \geq 0.22$). Marbling differed between implant treatments (433 to 466 ± 17.5; *P* = 0.02) for PLUS and ONE-F respectively. This is likely due to alterations of implant type on adipogenic gene expression (Kim et al., 2018; Smith et al., 2017) although this was not evaluated in the present study. Others have indicated that marbling is increased in heifers administered a single coated implant or an initial and terminal implant with a non-coated implant (Smith et al., 2020a; Smith et al., 2019a).

CONCLUSION

Feeding increased levels of corn silage in finishing diets does not alter live-basis growth performance; however, carcass-adjusted growth performance is decreased. Depending upon marketing options (live or dressed basis) these differing responses should be exploited to benefit the producer. When marketing on a HCW basis, using a lower level of corn silage in the finishing phase can result in heavier HCW when cattle are harvested on equal days on feed. Agronomic returns per hectare did not differ due to silage inclusion suggesting that integrated crop-livestock systems harvest and feed more corn silage without detriment to returns to a fixed land base. Terminal implant type (coated vs. non-coated) did not influence growth performance or carcass characteristics other than marbling scores. Use of these differing technologies in practice should be determined upon the method in which the beef cattle are marketed, cost of the implant, and the improvements in revenue for cattle that are rewarded a premium for greater quality grades.

LITERATURE CITED

AOAC. 2012. Official methods of analysis. 19th ed. Arlington, (VA): Association of Official Analytical Chemist.

AOAC. 2016. Official Methods of Analysis of AOAC International. 20 ed. Association of Official Analytical Chemist, Arlington, VA.

Cleale, R. M., D. T. Bechtol, J. S. Drouillard, J. D. Edmonds, M. Edmonds, B. D. Hunsaker, L. A. Kraft, T. E. Lawrence, S. Brewbaker, and A. R. Waite. 2012. Synovex Plus implants coated with a polymeric, porous film improve performance of beef steers and heifers fed in confinement for up to 200 days. Journal of Animal Science 90(13):5056-5066. doi: 10.2527/jas.2012-5091

DiCostanzo, A., C. Zehnder, H. Chester-Jones, D. Ziegler, and R. Greenwald. 1997. Effect of dietary com silage proportion on yearling steer performance and economic returns. Univ. of MN, St. Paul, MN. B-442:14-20.

Goering, H. K., and P. J. Van Soest. 1970. Forgae fiber analysis (Apparatus, reagents, procedures, and some application). Agric. Handbook No. 379. ARS, USDA, Washington, DC.

Goodrich, R., D. Crawford, M. Thonney, and J. Meiske. 1974. Influence of corn silage level on the performance and economic returns of steer calves. MN Cattle Feeder Rep. Univ. of MN, St. Paul, MN. B-195:14-19.

Guiroy, P., D. Fox, L. Tedeschi, M. Baker, and M. Cravey. 2001. Predicting individual feed requirements of cattle fed in groups. Journal of Animal Science 79(8):1983-1995.

Guiroy, P. J., L. O. Tedeschi, D. G. Fox, and J. P. Hutcheson. 2002. The effects of implant strategy on finished body weight of beef cattle. Journal of Animal Science 80(7):1791-1800. doi: 10.2527/2002.8071791x

Johnson, B., P. Anderson, J. Meiske, and W. R. Dayton. 1996. Effect of a combined trenbolone acetate and estradiol implant on feedlot performance, carcass characteristics, and carcass composition of feedlot steers. Journal of Animal Science 74(2):363-371.

Kim, J., Z. Smith, and B. Johnson. 2018. Coated and non-coated steroidal implants containing trenbolone acetate and estradiol benzoate on adipogenic gene expression of beef steers. Journal of Animal Science 96:240-241.

Murphey, C., D. Hallett, W. Tyler, and J. Pierce Jr. 1960. Estimating yields of retail cuts from beef carcasses. Journal of Animal Science 19(Suppl 1):1240.

NASEM. 2016. Nutrient Requirements of Beef Cattle. 8 ed.

National Academies of Sciences, E., and Medicine. 2016. Nutrient requirements of beef cattle. National Academies Press.

Preston, R. L. 2016. Feed Composition Table. BEEF Magazine

Rusche, W. C., J. A. Walker, and Z. K. Smith. 2020. Effect of inclusion rate of silage with or without alpha-amylase trait on finishing steer growth performance, carcass characteristics, and agronomic efficiency measures. Translational Animal Science 4(2):942-949. doi: 10.1093/tas/txaa056

Samuelson, K. L., M. E. Hubbert, M. L. Galyean, and C. A. Löest. 2016b. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. Journal of Animal Science 94(6):2648-2663. doi: 10.2527/jas.2016-0282

Smith, Z., K. Chung, S. Parr, and B. Johnson. 2017. Anabolic payout of terminal implant alters adipogenic gene expression of the longissimus muscle in beef steers. Journal of Animal Science 95(3):1197-1204.

Smith, Z., D. Renter, B. Holland, A. Word, G. Crawford, W. Nichols, B. Nuttelman, M. Streeter, L. Walter, and J. Hutcheson. 2020a. A pooled analysis of six large-pen feedlot studies: Effects of a non-coated initial and terminal implant compared with a single initial and delayed-release implant on arrival in feedlot heifers. Translational Animal Science 4(3):txaa109.

Smith, Z. K., P. T. Anderson, and B. J. Johnson. 2020b. Finishing Cattle in All-Natural and Conventional Production Systems. Open Journal of Animal Sciences 10(02):237.

Smith, Z. K., and B. J. Johnson. 2020. Mechanisms of steroidal implants to improve beef cattle growth: a review. Journal of Applied Animal Research 48(1):133-141. doi: 10.1080/09712119.2020.1751642

Smith, Z. K., B. J. Johnson, J. P. Hutcheson, M. N. Streeter, B. L. Nuttelman, W. N. Nichols, G. I. Crawford, A. B. Word, and B. P. Holland. 2019a. Effects of a single initial and delayed release implant on arrival compared with a non-coated initial implant and a non-coated terminal implant in heifers fed across various days on feed. Translational Animal Science 3(4):1182-1193. doi: 10.1093/tas/txz127

Smith, Z. K., J. Kim, and B. J. Johnson. 2019b. Feedlot performance and biological responses to coated and non-coated steroidal implants containing trenbolone acetate and estradiol benzoate in finishing beef steers123. Journal of Animal Science 97(11):4371-4385. doi: 10.1093/jas/skz298

USDA. 1997. United States standards for grades of carcass beef.

Van Soest, P. J., J. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74(10):3583-3597.

Zinn, R. 1987. Influence of lasalocid and monensin plus tylosin on comparative feeding value of steam-flaked versus dry-rolled corn in diets for feedlot cattle. Journal of Animal Science 65(1):256-266.

Zinn, R., and Y. Shen. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. Journal of Animal Science 76(5):1280-1289.

Table 2.1. Actual diet formulation and composition based upon weekly dry matter and nutrient composition determinations.[1,2]

	d 1 to 98				d 99 to 132			
Item	CS15	sd[3]	CS30	sd	CS15	sd	CS30	sd
Samples, n	15	-	15	-	5	-	5	-
High moisture corn, %	36.03	0.287	28.50	0.314	-	-	-	-
Dry rolled corn, %	36.61	0.346	28.97	0.397	73.00	0.230	57.87	0.295
Corn silage, %	15.34	0.445	30.55	0.729	15.24	0.171	30.40	0.277
Suspension supplement[4], %	5.02	0.052	5.00	0.072	4.90	0.065	4.89	0.063
Pelleted supplement[5], %	7.00	0.063	6.98	0.093	6.86	0.079	6.84	0.075
Dry matter, %	64.32	0.667	54.56	0.783	69.59	0.921	57.82	0.752
Crude protein, %	12.32	0.459	12.07	0.456	11.85	0.265	11.49	0.298
NDF[6], %	13.57	0.599	18.53	1.194	14.18	0.402	19.74	0.785
ADF[7], %	6.12	0.249	9.20	0.484	6.20	0.176	9.37	0.358
Ash, %	4.87	0.115	5.34	0.150	4.83	0.194	5.29	0.254
NEm[8,10], Mcal/kg	2.08	0.002	2.01	0.003	2.05	0.001	1.96	0.002
NEg[9,10], Mcal/kg	1.40	0.002	1.33	0.003	1.38	0.001	1.31	0.001

[1] All values except for dry matter (DM) on a DM basis.
[2] calculated from weekly ingredient assays and feed batching records
[3] sd = standard deviation
[4] Provided micronutrients to meet or exceed NRC (1996) requirements and provided 33 mg/kg (DM) monensin sodium.
[5] Contains (DM basis): 85.70% soybean meal, 2.85% trace mineralized salt, 2.85% urea, and 8.60% dry rolled corn.
[6]Neutral detergent fiber
[7]Acid detergent fiber
[8]Net energy for maintenance
[9]Net energy for gain
[10] Based upon tabular NE values for ingredients (Preston, 2016).

Table 2.2. Cumulative live (shrunk) and carcass-adjusted (HCW/0.63) growth performance responses and beef production per hectare of cropland in finishing diets containing 15% (CS15) or 30% (CS30) corn silage (DM basis) and non-coated (PLUS) or coated (ONE-F) implant containing 200 mg of trenbolone acetate and 28 mg of estradiol benzoate.[1]

	CS15		CS30			*P*-value		
Item	PLUS	ONE-F	PLUS	ONE-F	SEM[2]	Silage (S)	Implant (I)	S × I
Pens, n	5	5	5	5	-	-	-	-
Steers, n	38	37	36	38	-	-	-	-
Live basis[3]								
Initial BW, kg	370	369	368	368	-	-	-	-
Final BW, kg	589	586	582	587	8.0	0.62	0.86	0.51
ADG, kg	1.70	1.65	1.62	1.66	0.054	0.46	0.89	0.22
DMI, kg	10.10	9.92	10.08	10.21	0.169	0.29	0.85	0.22
G:F	0.168	0.166	0.161	0.163	0.005	0.19	1.00	0.60
Carcass-adjusted basis[4]								
BW, kg	603	601	589	590	6.622	0.02	0.86	0.70
ADG, kg	1.81	1.75	1.67	1.68	0.044	0.01	0.54	0.30
G:F	0.179	0.177	0.166	0.165	0.006	0.01	0.61	0.89
Observed dietary NE[5], Mcal/kg								
Maintenance	2.05	2.05	2.02	2.02	0.051	0.43	0.94	0.94
Gain	1.39	1.39	1.36	1.36	0.045	0.43	0.94	0.94
Observed to expected dietary NE[6]								
Maintenance	0.99	0.99	1.02	1.02	0.025	0.15	0.91	0.87
Gain	0.99	0.99	1.03	1.03	0.032	0.23	0.90	0.85
Agronomic return								
Live basis beef produced, kg/hectare	2027	2011	2087	2109	70.7	0.13	0.96	0.70
Carcass-adjusted beef produced, kg/hectare	2159	2137	2146	2131	42.3	0.76	0.56	0.92

[1] Deads and removals excluded
[2] SEM = standard error of the mean
[3] A 4% shrink was applied to all BW measures in order to account for gastrointestinal tract fill.
[4] Calculated from HCW/0.63
[5] Based upon live growth performance.

[6] Actual diet NE based upon tabular values and diet formulation were: 2.06 Mcal/kg of NEm and 1.40 Mcal/kg of NEg for CS15; 1.98 Mcal/kg of NEm and 1.32 Mcal/kg of NEg for CS30.

Table 2.3. Digestibility of dry matter, organic matter, and crude protein in finishing diets containing 15% (CS15) or 30% (CS30) corn silage (DM basis) and non-coated (PLUS) or coated (ONE-F) implant containing 200 mg of trenbolone acetate and 28 mg of estradiol benzoate.

	CS15		CS30			*P* - values		
Item	PLUS	ONE-F	PLUS	ONE-F	SEM[1]	Silage (S)	Implant (I)	S × I
n, Pens	5	5	4	5	-	-	-	-
DMI, kg	11.89	11.64	12.17	11.74	0.329	0.41	0.16	0.71
Fecal Output, kg	2.92	3.02	4.52	3.61	0.50	0.01	0.15	0.08
Nutrient digestibility, %								
Dry Matter	75.19	74.12	60.57	69.39	3.130	0.01	0.21	0.09
Organic Matter	76.95	75.86	64.96	71.30	2.923	0.01	0.20	0.08
Crude Protein	67.37	61.95	49.42	58.75	6.447	0.03	0.66	0.12

[1] SEM = standard error of the mean

Table 2.4. Carcass trait responses in finishing diets containing 15% (CS15) or 30% (CS30) corn silage (DM basis) and non-coated (PLUS) or coated (ONE-F) implant containing 200 mg of trenbolone acetate and 28 mg of estradiol benzoate.

	CS15		CS30			*P*-value		
Item	PLUS	ONE-F	PLUS	ONE-F	SEM[1]	Silage (S)	Implant (I)	S × I
Pens, n	5	5	5	5	-	-	-	-
Steers, n	38	37	36	38	-	-	-	-
Dressing percent[2], %	64.56	64.48	63.69	63.25	0.501	0.01	0.48	0.62
Hot carcass weight, kg	380	378	371	372	4.17	0.02	0.86	0.70
Ribeye area, cm^2	93.35	92.97	92.45	91.87	1.142	0.24	0.55	0.93
Rib fat, cm	1.14	1.07	1.12	0.99	0.112	0.53	0.22	0.71
Marbling score[3]	436	451	429	480	17.5	0.42	0.02	0.16
Yield Grade	2.67	2.61	2.62	2.52	0.139	0.50	0.43	0.87
Retail yield, %	50.75	50.88	50.86	51.04	0.279	0.50	0.45	0.88
Estimated empty body fat (EBF), %	28.54	28.32	28.26	28.12	0.676	0.63	0.71	0.93
Final BW at 28% EBF, kg	589	590	580	583	8.9	0.23	0.74	0.87
Select, %	31.43	19.64	34.28	19.64	8.459	0.87	0.14	0.87
Choice, %	63.21	70.00	57.03	63.57	8.369	0.46	0.44	0.99
Upper 2/3 choice, %	5.36	10.36	8.69	8.58	3.827	0.84	0.53	0.51
Prime, %	0.00	0.00	0.00	8.21	2.812	0.16	0.16	0.16
Yield Grade 1, %	10.71	16.78	9.17	13.93	5.303	0.68	0.62	0.90
Yield Grade 2, %	62.86	45.36	55.95	42.14	11.956	0.68	0.21	0.88
Yield Grade 3, %	26.43	37.86	34.88	43.93	11.479	0.54	0.39	0.92

[1] SEM = standard error of the mean
[2] Calculated as HCW/final BW shrunk 4%
[3] 400 = small^{00} (USDA Low Choice).

CHAPTER THREE

EFFECT OF COMPLETE REPLACEMENT OF DRY-ROLLED CORN WITH UNPROCESSED RYE ON GROWTH PERFORMANCE, EFFICIENCY OF DIETARY NET ENERGY USE, AND CARCASS TRAITS OF FINISHING HEIFERS

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ABSTRACT

Continental crossbred beef heifers were used in a randomized complete block design experiment to evaluate the effects of unprocessed rye in replacement of dry-rolled corn on finishing phase growth performance and efficiency of dietary net energy (NE) utilization. Fifty-six heifers (433 ± 34.0 kg BW) were transported 241-km from a sale barn in North Central South Dakota to the Ruminant Nutrition Center in Brookings, SD. Heifers were blocked by weight grouping and allotted to treatment pens (n = 7 heifers/pen and 4 pens/treatment). Treatments included a finishing diet that contained: 1) dry-rolled corn as the grain component of the diet (DRC) or 2) contained unprocessed rye as the grain component (RYE). On d 14 all heifers were consuming the final diet and heifers were implanted with 200 mg trenbolone acetate and 28 mg estradiol benzoate (Synovex-Plus, Zoetis, Parsippany, NJ). Heifer from DRC had greater ($P \leq 0.01$) final body weight, average daily gain, and gain efficiency; however, tended ($P = 0.08$) to have lesser DMI compared to RYE. Heifers from DRC had greater ($P \leq 0.01$) observed dietary NE maintenance and gain; heifers from DRC also had a greater ($P \leq 0.01$) observed-to-expected dietary NE for maintenance and gain ratio compared to RYE. Dressing percentage, 12th rib fat thickness, ribeye area, and the distribution of USDA Yield and Quality grade were not altered ($P \geq 0.12$) by dietary treatment. Hot carcass weight, calculated yield grade, estimated empty body fatness (EBF), and body weight at 28% EBF were increased ($P \leq 0.02$) in DRC compared to RYE; and retail yield was decreased ($P = 0.01$) in DRC compared to RYE heifers. These data indicate that unprocessed rye is a palatable feed ingredient for inclusion in finishing diets for beef cattle and rye inclusion only minimally influences carcass quality grade. The feeding value of unprocessed rye is

considerably less than that of dry-rolled corn and approximately 90% the net energy value of processed rye.

INTRODUCTION

Crop-rotation diversity has many benefits to integrated crop-livestock production systems. These include yield resiliency and crop yield increases compared to single or two-crop rotation systems (Bowles et al., 2020). When combined with livestock production, diversified crop-rotations can reduces year-round variation in labor requirements compared to a traditional corn-soybean rotation coupled with livestock production (Poffenbarger et al., 2017).

Cereal rye deserves consideration for use as a component of an integrated crops-livestock system. Rye is a multi-use crop than can be grazed, harvested for forage, or harvest for grain and straw. Plus, rye is harvested earlier than other traditionally used row crops allowing for greater flexibility related to manure application or the use of short-season forage crops to be fed to livestock if weather and market conditions are appropriate. Hybrid rye germplasms that have recently become available to the United States from Europe are of particular interest because of enhanced yield potential and decreased ergot incidence compared to traditional open-pollinated rye varieties (Hansen et al., 2004).

Previous research from this lab have indicated that processed rye (processing index of 78.8%) was a suitable ingredient (84% the net energy value of dry-rolled corn) for use in finishing (Rusche et al., 2020). Rusche et al. (2020) demonstrated that the apparent net energy (NE) value for gain of processed rye was increased by 12.8% when blended with dry-rolled corn (1/3 processed rye and 2/3 dry-rolled corn) in finishing diets fed to yearling feedlot steers compared to complete replacement of dry-rolled corn with processed rye. A major impediment to use of rye in finishing diets is that rye should be processed prior to feeding. Processing rye requires differing equipment or altered settings compared to what is required for processing corn as dry-rolled corn, hence for the operation to use and feed processed rye requires either substantial investment or increased feed mill operational complexity.

The objective of this experiment was to determine the effects that complete replacement of dry-rolled corn with unprocessed rye have on dry matter intake, growth performance, and feed efficiency in finishing beef heifers. Our hypothesis was that unprocessed cereal rye could be substituted for dry-rolled corn in finishing beef diets but would result in poorer growth performance and feed efficiency with no negative effects on carcass characteristics.

MATERIALS AND METHODS

Animal care and handling procedures used in this study were approved by the South Dakota State University Animal Care and Use Committee (Approval Number: 2007-031E).

Animal Management and Dietary Treatments

Heifers were used to evaluate the effect of unprocessed rye in replacement of dry-rolled corn on finishing phase growth performance and efficiency of dietary NE utilization. Fifty-six crossbred beef heifers (433± 34.0 kg BW) were transported 241-km from a sale barn in North Central South Dakota to the Ruminant Nutrition Center (RNC) in Brookings, SD on August 24, 2020. Upon arrival to the RNC, heifers were housed in 7.62 m × 7.62 m concrete surface pens with 7.62 m of linear bunk-space and provided ad libitum access to long-stem grass hay and water. On August 27, 2020 (3-d following arrival) all heifers were individually weighed (scale readability 0.454 kg), applied a unique identification ear tag, vaccinated for viral respiratory pathogens: IBR, BVD 1 and 2, PI3, and BRSV (Bovi-Shield Gold 5, Zoetis, Parsippany, NJ) and clostridials (Ultrabac 7/Somubas, Zoetis) as well as administered pour-on moxidectin (Cydectin, Bayer, Shawnee Mission, KS) according to label directions. On September 1, 2020 (9-d following arrival), all heifers were again individually weighed, and this body weight was used for allotment purposes. Heifers were blocked by weight grouping and allotted to their study pens the following day (n = 7 heifers/pen and 4 pens/treatment) and test diets were initiated. Treatments included a finishing diet that contained: 1) dry-rolled corn as the grain component of the diet (DRC) or 2) contained unprocessed hybrid rye as the grain component (RYE). On d 14 all heifers were consuming the final diet and were implanted with 200 mg trenbolone acetate and 28 mg estradiol benzoate (Synovex-Plus, Zoetis); an implant retention check occurred on d 42. The initial BW was the BW captured on September 2, 2020. Following study initiation, heifers were transitioned to the high concentrate diet over the course of 14 d (Table 3.1). Diets were fortified to provide vitamins and minerals to meet or exceed nutrient requirements, provided monensin sodium at 33.1 g/Mg (DM basis) and melengestrol acetate (MGA, Zoetis) at a rate sufficient to provide 0.50 mg/heifer$\cdot$d^{-1} (NASEM, 2016). There was no morbidity or mortality noted in the present study. Fresh feed was manufactured twice daily in a stationary mixer (2.35 m^3; scale readability 0.454 kg) and offered to heifers in equal amounts at each feeding. 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 the quantity of dry orts for each interim period. Actual diet formulation is based upon weekly DM analyses (drying at 60 °C till no weight change) and corresponding feed batching records. After weekly DM determination (method no. 935.29; (AOAC, 2012)), monthly composite samples from each ingredient were analyzed for N (method no. 968.06;(AOAC, 2016); Rapid Max N Exceed; Elementar; Mt. Laurel, NJ), and ash (method no. 942.05;(AOAC, 2012)). Corn co-products were analyzed for ether extract content using an Ankom Fat Extractor (XT10; Ankom Technology, Macedon, NY). Percentages of ADF and NDF were assumed to be 3 and 9 % for DRC and 9 and 19 % for Rye, respectively. Analysis of ADF and NDF composition for all other feeds was conducted as described by (Goering & Van Soest, 1970). Diets presented in Table 3.1 are actual DM diet composition, monthly composite nutrient concentrations, and tabular energy values (Preston, 2016).

Growth Performance Calculations

Heifers were individually weighed on d -1, 1, 14, 42, and 77. Cumulative growth performance was based upon shrunk BW from d 1 (4% shrink applied to account for digestive tract fill) and carcass-adjusted final BW (FBW; HCW/0.625). The energetic assessment period was from d 14 to 77 using BW from d 14 shrunk 4% and FBW. Average daily gain (ADG) was calculated as the difference in BW for the period of interest, divided by the days in that period and feed efficiency was calculated from ADG/DMI.

Carcass trait determination

Heifers were harvested when they were visually appraised to have 1.27 cm of rib fat (RF). Heifers were shipped the afternoon following final BW determination and harvested the next day at Tyson Fresh Meats in Dakota City, NE. Heifers were comingled at the time of study termination and remained as such until 0700 h the morning after shipping. Hot carcass weight (HCW) was captured immediately following the harvest procedure. Video image data were obtained from the plant for ribeye area, RF, and USDA marbling scores. Yield grade was calculated according to the USDA regression equation (USDA, 1997). Dressing percentage 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 proportion of closely trimmed boneless retail cuts from carcass round, loin, rib, and chuck (Retail Yield, RY; (Murphey et al., 1960)). Carcass data were available for all heifers except one heifer from the RYE treatment.

Efficiency of dietary NE utilization calculations

Observed dietary NE was calculated from daily energy gain (EG; Mcal/d): EG = (Carcass-adjusted ADG from d 14 to 77)$^{1.097}$ × 0.0557W$^{0.75}$, where W is the mean equivalent BW [average BW (using d 14 shrunk BW and FBW) × (478/AFBW), kg;

(NRC, 1996)]. Maintenance energy required (EM; Mcal/d) was calculated by the following equation: EM = $0.077BW^{0.75}$ (Lofgreen and Garrett, 1968) where BW is the mean shrunk BW (using the average of FBW and BW from d 14). Using the estimates required for maintenance and gain the observed dietary NEm and NEg values (Owens & Hicks, 2019), of the diet were generated using the quadratic formula: $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$ where x = NEm, Mcal/kg, a = -0.41EM, b = 0.877EM + 0.41DMI + EG, c = -0.877DMI, and NEg was determined from: 0.877NEm – 0.41 (Zinn et al., 2008; Zinn & Shen, 1998). The ratio of observed-to-expected NE ratio was determined from observed dietary NE for maintenance or gain/tabular NE for maintenance or gain.

Statistical analysis

Growth performance, carcass traits, and efficiency of dietary NE utilization were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. The model included the fixed effect of dietary treatment; and block (initial weight grouping) was included as a random variable. Least squares means were generated using the LSMEANS statement of SAS and treatment effects were analyzed using the pairwise comparisons PDIFF and LINES option of SAS 9.4. Distribution of USDA Yield and Quality grade data were analyzed as binomial proportions in the GLIMMIX procedure of SAS 9.4 with fixed and random effects in the model as described previously. An α of 0.05 or less determined significance and tendencies are discussed between 0.05 and 0.10.

RESULTS AND DISCUSSION

Cumulative Growth Performance (d 1 to 77)

Growth performance responses are located in Table 3.2. There was no difference between treatments for initial BW (*P* = 0.72). Final BW was decreased by 6.8% for RYE compared to DRC (*P* = 0.01), accordingly, ADG was decreased by 27.6% for heifers fed RYE compared to DRC (*P* = 0.01). It has been demonstrated previously that complete replacement of dry-rolled corn with processed rye resulted in decreased growth performance in finishing steers (Rusche et al., 2020). Cumulative DMI tended to be greater for heifers fed RYE by 6.4% compared to heifers in the DRC treatment (*P* = 0.08); as such, feed efficiency was decreased by 32.3% for heifers in RYE compared to heifers from DRC. Others have indicated that as increasing amounts of processed rye was included in finishing diets, DMI and gain efficiency was linearly decreased (Rusche et al., 2020).

Energetics Assessment Period (d 14 to 77)

Data from the energetics assessment period are provided in Table 3.2. The BW on day 14 did not differ between treatments (*P* = 0.50). As previously mentioned, the final BW decreased by 6.8% in RYE heifers compared to DRC heifers. During the energetics assessment period, the ADG decreased by 29.0% (*P* = 0.01), and the DMI tended to be greater by 7.0% (*P* = 0.08) in RYE compared to DRC heifers. Complete replacement of dry-rolled corn with processed rye was shown to result in decreased intake and growth performance in finishing steers (Rusche et al., 2020). Alterations in daily gain and intake translated into reduced gain to a feed efficiency of 33.7% in RYE compared to DRC heifers (*P* = 0.01). Observed dietary NEm increased by 34.7% (*P* = 0.01) and observed dietary NEg increased by 46.8% in DRC compared to RYE heifers (*P* = 0.01). The observed-to-expected NE ratio for maintenance and gain also increased in DRC compared to RYE heifers ($P \leq 0.01$). The observed-to-expected NEm ratio for the DRC diet was 1.14, far from the expected ratio of 1.00. Thus, applying substitution, the corresponding NEm value for dry-rolled corn is 2.73 Mcal/kg. This NE value is much greater than what current standards indicate (NASEM, 2016), and if this value is used to estimate energy derivations by the replacement technique, it will result in aberrant values. The comparative energy value for unprocessed rye fed in the present study can be determined using the substitution technique to fit the NE value of the RYE diet, assuming that the NE content of the rest of the ingredients is constant, and only the NE of rye grain is adjusted to fit the observed diet NE. The NEg (Mcal/kg) value of the ingredient can be derived from NEm using the equation (NEg, Mcal/kg): 0.877NEm − 0.41 (Zinn and Shen, 1998; Zinn et al., 2008). Accordingly, the NEm and NEg values for unprocessed rye are 1.73 and 1.11, Mcal/kg, respectively. Hence, based on growth performance, the NE value for unprocessed rye grain represents 78.6% of the energy value assigned by (NASEM, 2016) for dry-rolled corn. This value of 1.73 Mcal/kg NEm is 9% less than the NEm value reported by (Rusche et al., 2020), who determined that the estimated NE value for rye grain processed to a processing index of 78.8% was 86% of the NE value for dry-rolled corn (Rusche et al., 2020). This indicates that regardless of the processing method, rye grain has less than 90% the NE value of dry-rolled corn. When comparing the results of the present study with those presented by (Rusche et al., 2020), processing rye grain increases the NE value of rye by nearly 9%. This corresponds well to estimates for improvements in the NE value when small grains such barley or wheat are dry-rolled compared to when they are fed unprocessed (Zinn, 1993, 1994; Mathison, 1996; Preston, 2016).

Carcass traits

Carcass trait responses are located in Table 3.3. Heifers from DRC had a 7.5% increase in HCW compared to heifers from RYE (P = 0.01). Dressing percentage was did not influenced (P = 0.12) by dietary treatment. A reduction in HCW and dressing percentage has been demonstrated when processed rye was fed in replacement of dry-rolled corn (Rusche et al., 2020). Ribeye area and 12th rib fat thickness did not differ (P ≥ 0.14) due to dietary treatment. Marbling score tended (P = 0.10) to be greater by 12.7% in DRC heifers compared to RYE heifers. Calculated yield grade was increased by 9.6% and retail yield was decreased by 1.0% in DRC heifers compared to heifers from RYE (P ≤ 0.01). Heifers from DRC had greater estimated EBF by 5.1% compared to heifers from the RYE treatment (P = 0.02) and final BW at 28% EBF was decreased (P = 0.01) by 12 kg in RYE heifers compared to DRC heifers. There was no influence (P ≥ 0.13) of dietary treatment on the distribution of USDA Yield or Quality grades. Others have indicated that partial or complete replacement of dry-rolled corn with rye had minimal influence on the distribution of USDA Yield or Quality grades (Rusche et al., 2020).

CONCLUSION

It is concluded that unprocessed rye is a palatable feed ingredient for inclusion in finishing diets for beef cattle and only minimally influences carcass quality grade. The feeding value of unprocessed rye is considerably less than that of dry-rolled corn and approximately 90% the net energy value of processed rye. Hence, gain efficiency will be correspondingly lower when unprocessed rye is fed in replacement of dry-rolled corn or processed rye in feedlot finishing diets fed to cattle.

Table 3.1. Actual diet formulation and composition based upon weekly DM determinations and monthly ingredient composite nutrient compositions.[1]

	d 1 to 4		d 5 to 14		d 15 to 37		d 38 to 59		d 60 to 77	
Item	DRC	RYE	DRC	RYE	DRC	RYE	DRC	RYE	DRC	RYE
DRC[2], %	39.36	-	49.60	-	59.59	-	60.09	-	60.27	-
Unprocessed rye, %	-	39.58	-	49.89	-	59.68	-	60.00	-	60.18
CBCDS[3], %	19.77	19.70	19.62	19.51	20.17	20.12	19.80	19.84	-	-
DDGS[4], %	-	-	-	-	-	-	-	-	19.70	19.75
Grass hay, %	29.09	28.99	18.88	18.77	8.37	8.35	-	-	-	-
Oat hay, %	-	-	-	-	-	-	8.17	8.19	8.06	8.08
Meal suplement[5], %	6.91	6.88	6.99	6.95	7.00	6.98	7.03	7.05	7.03	7.04
Pelleted supplement[6], %	4.87	4.85	-	-	-	-	-	-	-	-
Liquid supplement[7], %	-	-	4.92	4.89	4.87	4.86	4.92	4.93	4.95	4.95
Dry matter, %	75.57	76.37	74.08	75.14	75.02	75.97	74.32	74.92	87.62	88.51
Crude protein, %	12.82	14.81	12.46	14.96	12.86	15.79	12.97	15.71	13.69	16.43
NDF[8], %	34.79	38.65	28.35	33.23	21.14	27.09	19.65	25.68	20.18	26.22
ADF[9], %	18.62	20.94	14.54	17.46	9.84	13.41	8.78	12.40	9.25	12.87

Ash, %	9.02	9.23	7.51	7.78	6.84	7.16	6.72	7.03	6.04	6.35
EE[10], %	3.47	2.76	3.59	2.70	3.70	2.62	3.75	2.67	4.51	3.43
NEm[11], Mcal/kg	1.81	1.69	1.93	1.77	2.02	1.84	2.03	1.84	2.06	1.88
NEg[12], Mcal/kg	1.14	1.04	1.25	1.13	1.35	1.20	1.35	1.20	1.38	1.24

[1] All values except for dry matter (DM) on a DM basis.

[2] Dry-rolled corn.

[3] Corn bran plus condensed distillers solubles.

[4] Dried distillers grains plus soulubles.

[5] Contains (DM basis): 42.85% soybean hulls, 8.57% calcium carbonate, 48.58% ground corn and melengestrol acetate (MGA, Zoetis, Parsippany, NJ) sufficient to provide 0.50 mg/heifer·d^{-1}.

[6] Pelleted supplement contained (DM basis): 63% soybean meal, 12.3% soybean hulls, 5.0% trace mineralized salt, 18.5% calcium carbonate, and 1.2% of a vitamin premix that contained (in each 907-kg of supplement): 7,123 g of SBM, 2,022 g of Rumensin-90 (Elanco, Indianapolis, IN), 49 g of vitamin A (650,000 IU/g), 769 g of vitamin E (500 IU/g), 726 g of Intellibond Zn (Micronutrients, Indianapolis, IN) , and 201 g Intellibond Cu (Micronutients) for 0% GH.

[7] Liquid supplement contained (DM basis): 43.26% CP, 38.83% non-protein nitrogen, 43 Mcal/cwt of NEm, 29 Mcal/cwt of NEg, 1.07% ether extract, 13.18% total sugars, 54.02% ash, 11.02% calcium, 0.35% P, 7.08% K, 0.22% Mg, 5.05% NaCl, 2.93% Na, 0.39% S, 4.28 ppm Co, 202.18 ppm Cu, 12.13 ppm I, 6.92 mg/lb ethylenediamine dihydroiodide (EDDI), 113.72 ppm Fe, 308.33 ppm Mn, 2.93 ppm Se, 672.26 ppm Zn, 20,218.34 IU/lb Vitamin A, 202.18 IU/lb vitamin E, and 586.04 g/ton monensin sodium (Rumensin, Elanco, Indianapolis, IN).

[8] Neutral detergent fiber.

[9] Acid detergent fiber.

[10] Ether extract.

[11] Net energy for maintenance.

[12] Net energy for gain.

Table 3.2. Growth performance responses and efficiency of dietary net energy (NE) utilization.

Item	Dietary Treatment		SEM[1]	*P* - value
	Dry-rolled corn (DRC)	Unprocessed rye (RYE)		
Pens, n	4	4	-	-
Heifers, n	28	28	-	-
Cumulative d 1 to 77				
Initial BW[2], kg	433	434	1.6	0.72
Final BW[3], kg	576	537	8.8	0.01
ADG, kg	1.85	1.34	0.047	0.01
DMI, kg	11.52	12.26	0.277	0.08
G:F	0.161	0.109	0.0040	0.01
Energetic assessment period (d 14 to 77)				
BW 14[2], kg	449	447	3.2	0.50
Final BW[3], kg	576	537	8.8	0.01
ADG, kg	2.00	1.42	0.037	0.01
DMI, kg	12.35	13.22	0.339	0.08
G:F	0.163	0.108	0.0054	0.01
Observed dietary NE, Mcal/kg				
Maintenance	2.17	1.76	0.027	0.01
Gain	1.49	1.13	0.024	0.01
Observed-to-expected dietary NE[4]				
O/E NEm	1.06	0.95	0.014	0.01
O/E NEg	1.10	0.94	0.018	0.01

[1] SEM = standard error of the mean

[2]BW was shrunk 4% to account for digestive tract fill.

[3] HCW/0.625.

[4] Tabular NE (Mcal/kg) during the energetic assessment period for DRC was 2.04 and 1.36 for maintenance and gain, respectively; for RYE was 1.83 and 1.21 for maintenance and gain, respectively; The tabular NEm and NEg for the dry-rolled corn was assumed to be 2.20 Mcal/kg NEm and 1.50 Mcal/kg NEg; the tabular NEm and NEg for unprocessed rye was assumed to be 1.90 Mcal/kg NEm and 1.26 Mcal/kg NEg.

Table 3.3. Carcass trait responses.

Item	Dietary Treatment		SEM[1]	*P* - value
	Dry-rolled corn (DRC)	Unprocessed rye (RYE)		
Pens, *n*	4	4	-	-
Heifers, *n*	28	27	-	-
HCW, kg	360	335	2.6	0.01
DP[2], %	61.68	60.64	0.477	0.12
RF, cm	1.32	1.19	0.069	0.14
REA, cm^2	87.40	85.79	1.535	0.37
Marbling[3]	506	449	24.5	0.10
Yield grade	2.98	2.72	0.032	0.01
Retail yield[4], %	50.12	50.65	0.072	0.01
Estimated empty body fatness [5], %	30.00	28.54	0.296	0.02
Final BW at 28% EBF [5], kg	535	523	1.4	0.01
YG[6] distribution				
Y1, %	0.0	3.6	2.52	0.39
Y2, %	42.8	59.5	13.78	0.13
Y3, %	53.6	36.9	15.29	0.26
Y4, %	3.6	0.0	2.52	0.39
QG distribution[7]				
Select, %	10.7	33.3	9.85	0.16
Choice,	35.7	40.5	12.82	0.81
Average Choice, %	35.7	22.0	10.85	0.44
Top Choice, %	10.7	4.2	5.66	0.47
Prime, %	7.1	0.0	5.05	0.39

[1] SEM = standard error of the means
[2] HCW/final BW shrunk 4%.
[3] USDA Marbling Score 400 = Small[00] = Low Choice; 500 = Modest[00] = Average Choice.
[4] As a percentage of HCW.
[5]According to the equations described by Guiroy et al. (2002).
[6]Yield Grade
[7]USDA Quality Grade distribution

LITERATURE CITED

AOAC. 2012. Official methods of analysis. 19th ed. Arlington, (VA): Association of Official Analytical Chemist.

AOAC. 2016. Official Methods of Analysis of AOAC International. 20 ed. Association of Official Analytical Chemist, Arlington, VA.

Bowles, T. M., M. Mooshammer, Y. Socolar, F. Calderón, M. A. Cavigelli, S. W. Culman, W. Deen, C. F. Drury, A. Garcia y Garcia, A. C. M. Gaudin, W. S. Harkcom, R. M. Lehman, S. L. Osborne, G. P. Robertson, J. Salerno, M. R. Schmer, J. Strock, and A. S. Grandy. 2020. Long-Term Evidence Shows that Crop-Rotation Diversification Increases Agricultural Resilience to Adverse Growing Conditions in North America. One Earth 2(3):284-293. doi: https://doi.org/10.1016/j.oneear.2020.02.007

Goering, H. K., and P. J. Van Soest. 1970. Forgae fiber analysis (Apparatus, reagents, procedures, and some application). . Agric. Handbook No. 379. ARS, USDA, Washington, DC.

Guiroy, P. J., L. O. Tedeschi, D. G. Fox, and J. P. Hutcheson. 2002. The effects of implant strategy on finished body weight of beef cattle. J. Anim. Sci. 80(7):1791-1800. doi: 10.2527/2002.8071791x

Hansen, H. B., B. Møller, S. B. Andersen, J. R. Jørgensen, and Å. Hansen. 2004. Grain characteristics, chemical composition, and functional properties of rye (Secale cereale L.) as influenced by genotype and harvest year. J. Agr. Food Chem. 52(8):2282-2291. doi: 10.1021/jf0307191

Lofgreen, G. P., and W. N. Garrett. 1968. A System for Expressing Net Energy Requirements and Feed Values for Growing and Finishing Beef Cattle. J. Anim. Sci. 27(3):793-806. doi: 10.2527/jas1968.273793x

Mathison, G. W. 1996. Effects of processing on the utilization of grain by cattle. Animal Feed Science and Technology 58(1):113-125. doi: https://doi.org/10.1016/0377-8401(95)00878-0

Murphey, C. E., D. K. Hallett, W. E. Tyler, and J. C. Pierce. 1960. Estimating yields of retail cuts from beef carcass. Proc. Am. Soc. Anima. Prod., Chicago, IL.

NASEM. 2016. Nutrient Requirements of Beef Cattle. 8 ed.

NRC. 1996. Nutrient Requirements of Beef Cattle. 6th rev. ed. Natl. Acad. Press, Washington, D. C.

Owens, F. N., and R. B. Hicks. 2019. Can net energy values be determined from animal performance measurements? A review of factors affecting application of the California Net Energy System. Transl. Anim. Sci. 3(3):929-944. doi: 10.1093/tas/txy130

Poffenbarger, H., G. Artz, G. Dahlke, W. Edwards, M. Hanna, J. Russell, H. Sellers, and M. Liebman. 2017. An economic analysis of integrated crop-livestock systems in Iowa, U.S.A. Agr. Syst. 157:51-69. doi: https://doi.org/10.1016/j.agsy.2017.07.001

Preston, R. L. 2016. 2016 feed composition table BEEF Magazine. https://www.beefmagazine.com/sites/beefmagazine.com/files/2016-feedcomposition-tables-beef-magazine.pdf. (Accessed February 1, 2019).

Rusche, W. C., J. A. Walker, P. Sexton, R. S. Brattain, and Z. K. Smith. 2020. Evaluation of hybrid rye on growth performance, carcass traits, and efficiency of net energy utilization in finishing steers. Translational Animal Science 4(3)doi: 10.1093/tas/txaa173

USDA. 1997. Official United States Standard for Grades of Beef Carcasses Agric. Marketing, USDA Washington DC.

Zinn, R. A. 1993. Influence of processing on the comparative feeding value of barley for feedlot cattle. J Anim Sci 71(1):3-10. doi: 10.2527/1993.7113

Zinn, R. A. 1994. Influence of flake thickness on the feeding value of steam-rolled wheat for feedlot cattle. J Anim Sci 72(1):21-28. doi: 10.2527/1994.72121x

Zinn, R. A., A. Barreras, F. N. Owens, and A. Plascencia. 2008. Performance by feedlot steers and heifers: Daily gain, mature body weight, dry matter intake, and dietary energetics. J. Anim. Sci. 86(10):2680-2689. doi: 10.2527/jas.2007-0561

Zinn, R. A., and Y. Shen. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. J. Anim. Sci. 76(5):1280-1289. doi: 10.2527/1998.7651280x