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2023 Nebraska Beef Cattle Report

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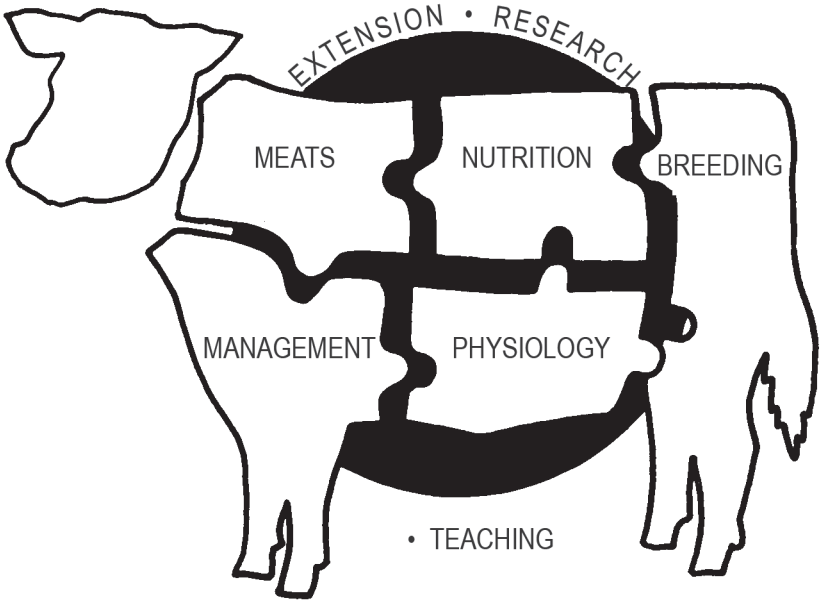

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2023 Beef Cattle Report

University of Nebraska Lincoln

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Comparison of Semi-confined and Pasture-based August Calving Beef Cow Systems

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Summary with Implications

Limited pasture availability and increased pasture rental rates have generated a need to evaluate alternative cow-calf production systems. The current study compared cow and calf performance in two August-calving cow systems that combined corn residue grazing with 1) perennial forage grazing and hay or 2) summer drylot feeding and fall cover crop grazing. Differences in pregnancy rates between systems within year were not observed; however, the effect of production system on cow body condition and calf body weight at different time points varied across years. Overall, cow and calf performance were not negatively impacted in the drylot/cropland system, suggesting that it is a potential alternative to a perennial forage-based system.

Introduction

Grass availability has decreased in Nebraska and in most of the Northern Plains region because of increased conversion of pasture acres to cropland, which has caused pasture rental rates to rise. The reduction in pasture resources and increased pasture rental rates has prompted a need to evaluate alternative feeding and management strategies for cow-calf production. Previous work has demonstrated that adequate cow body condition can be maintained on rations containing by-products and low quality forages (*2012 Nebraska Beef Cattle Report*, pp. 13–14).

A forage option for fall grazing that has increased in popularity is cover crops planted in late summer following wheat or corn silage harvest. In addition to the soil health benefits and weed control cover crops provide, late summer planted oats and brassica can provide a high-quality forage that maintains its nutritive value through the fall and into winter. When late summer planted oats were incorporated as a fall grazing option for an August-calving cow system with summer confinement and compared to a traditional, April-calving system with perennial pasture grazing, no differences in cow reproductive performance were observed (*2022 Nebraska Beef Cattle Report*, pp. 10–14). In the same study, however, calves in the summer confinement system had lighter weaning weights compared to calves in the spring-calving system, a result which may have been related to the time of year the calves were born. The objective of this study was to compare beef cow and calf performance in August-calving cow systems that utilized perennial pasture or summer drylot with fall cover crop grazing.

Procedure

Multiparous beef cows were utilized in a 3-year study conducted at the U.S. Meat Animal Research Center. In Year 1, cows bred to calve in August were stratified by age (n = 229; 5.3 ± 2.0 yr) and randomly assigned to 8 different herds. Each herd was then randomly assigned to a production system (i.e, 4 herds/system) utilizing either perennial forage and corn residue grazing (PF) or a system that incorporated summer drylotting, fall grazing of a late-summer planted cover crop, and corn residue grazing (DC). Cows remained in the herd that they were assigned to for the duration of the study and were removed from the study if they were diagnosed to be open at palpation, if they or their calf were seriously ill or injured, or died before weaning.

General management of cattle

In the first year, the study began in February. Calving each year began in August and lasted approximately 63 d. Cows in the PF and DC system calved while on pasture or in the drylot, respectively. Herds within PF and DC treatments were combined into 1 or 2 groups, respectively, during the breeding season in November. When calves were weaned (January/February), cows were sorted back into their herds and turned out on corn residue. Free choice mineral supplement was provided to cows while on corn residue. The new production year began in subsequent years when cows finished grazing corn residue (February/March) and were returned to either pasture or the drylot. If cows were removed from study, replacements were added at this time in a way that kept age stratification similar across herds. Body condition scores (BCS; 1 to 9) were collected on cows at the start of each production year (February), pre-calving (July), and breeding (October). Pregnancy diagnosis via rectal palpation occurred in February. Weights on calves were collected at birth, breeding, and weaning.

Management Year 1

Cows were placed on study February 15. The calving season began on August 4 and concluded on September 26. Bulls were turned in on November 5 for 44 d, and the cow to bull ratio was 25:1. Calves were weaned on January 14 at 143 days of age (DOA), and cows were subsequently turned out onto corn residue for 30 d. Pregnancy diagnosis occurred on February 13 following corn residue grazing. Due to limited residue availability, cows were offered free-choice alfalfa/grass hay for the duration of the corn residue grazing period.

Perennial forage-based system

Cows were placed on dormant forage pastures and fed free-choice alfalfa/grass hay starting in February until the middle of April and herds were managed as separate treatment groups. In April, cows grazed pastures until October 25, at which

Table 1. Dietary and nutrient composition of rations fed to cows in the drylot.

	Year 1 and 2		Year 3	
Ingredient, % of DM	Gestation[1]	Lactation[2]	Gestation[3]	Lactation[4]
Corn stalks	75.2	60.4	-	-
WDGS[5]	22.5	22.4	-	-
Corn silage	-	-	48.4	48.3
Alfalfa hay	-	-	48.4	48.3
Corn, dry-rolled	-	14.6	-	-
Supplemental pellet[6]	2.3	2.6	3.2	3.4
Diet nutrient content, % of DM				
CP	11.5	11.9	14.0	
TDN	63.3	69.0	61.5	

[1]Fed at a rate of 25.8 lb DM/cow/d from February to two weeks prior to the start of calving to cows on DC treatment.

[2]Fed at a rate of 27.9 lb DM/cow/d from two weeks prior to calving until late October to DC cows; cows on PF treatment fed from late October to late January in Year 2.

[3]Fed at a rate of 20.1 lb DM/cow/d from February to two weeks prior to the start of calving to cows on DC treatment.

[4]Fed at a rate of 20.8 lb DM/cow/d from two weeks prior to calving until November 1 to DC cows.

[5]Wet distillers grains with solubles.

[6]Pellet provided vitamins, minerals, and supplied 103 and 205 mg Rumensin/cow/d when fed in gestation and lactation rations, respectively.

time all herds were then combined into a single group and moved to a stockpiled field of brown mid-rib forage sorghum for breeding. Calves were creep fed ad libitum alfalfa hay surrounded by a single-wire fence beginning on October 31. When bulls were turned in on November 5, cows were offered free-choice alfalfa/grass hay.

Drylot/cropland system

Cows were placed in the drylot beginning in February and fed a total mixed ration (TMR; Table 1) that consisted of corn stalks and wet distillers grains with solubles (WDGS). Additionally, cows received 0.5 lb/hd of a supplemental pellet that contained vitamins, minerals, and 205 mg Rumensin/lb dry matter. Starting two weeks before expected calving date, dry-rolled corn was added to the diet, and supplemental pellet amount was increased to 1 lb/hd.

Starting October 1 while cows were in the drylot, calves were creep fed ad libitum alfalfa hay. Cows were sorted into two breeding groups such that DC treatment groups were equally represented within each breeding group. Cover crop was planted late in this year and was not ready for grazing by October 25, so one group was placed on an alfalfa/orchard grass mix pasture and the other group was placed on an alfalfa/endophyte-free tall fescue mix pasture.

Management Year 2

The production year started on February 14. Calving season started on July 25 and ended on September 26. Bulls were placed with cows on November 5 for 46 d, and cow to bull ratio was 20:1. Calves were weaned at 157 DOA on January 28, and cows were palpated on February 1 before being turned out to corn residue for 43 d. Supplemental alfalfa/grass hay was provided free-choice to cows while grazing corn residue starting on February 9.

Perennial forage-based system

On February 14, cows were placed on dormant forage pastures and fed free-choice alfalfa/grass hay until April, and grazed summer pasture until the end of October. Because of limited pasture availability due to drought, cows were maintained in their treatment groups and moved to the drylot on October 29 for breeding. Cows were fed a TMR that consisted of corn stalks, WDGS, and dry-rolled corn to meet energy requirements (Table 1). In addition, cows received 1 lb/hd/d of a supplemental pellet that supplied vitamins, minerals, and 205 mg Rumensin. Starting on October 30, calves were allowed ad libitum access to alfalfa hay via a single-wire fence creep area.

Drylot/cropland system

From February 14 through October 27 rations and management of cows was as described in Year 1. Calves were creep fed alfalfa hay as described in Year 1 beginning September 29 until cattle were moved to cover crops. Cows were sorted into two breeding groups such that DC treatment groups were equally represented within each breeding group and placed on a cover crop. The cover crop was planted August 22–23 using 55 lb/acre oats, 20 lb/acre cereal rye, and 3 lb/acre rapeseed. Breeding groups starting grazing cover crop on October 28 for 85 days until calves were weaned and cows were moved to corn residue. Beginning December 28, cows were provided free-choice alfalfa hay while they were on cover crops. Cows were returned to the drylot after corn residue grazing ended on March 12.

Management Year 3

The final year of the study began in mid-March when the corn residue grazing ended from the previous year. Calving season went from August 2 to September 27, and calves were weaned at 164 DOA on February 4. Bulls were placed with cows for breeding on November 16 and the breeding season lasted for 49 d, and the cow to bull ratio was 11:1. The study ended after cows were palpated on February 9.

Perennial forage-based system

Cows were placed on pasture and received no additional forage supplementation until December 1 during breeding, at which time they began receiving free-choice alfalfa/grass hay. On October 25, all herds in the PF treatment were combined into a single group for breeding and were moved to a single dormant forage pasture. Calves were ad libitum creep fed alfalfa hay as described in Years 1 and 2 starting January 1.

Drylot/cropland system

Cows received a TMR that consisted of corn silage, ground alfalfa hay, and supplemental pellet (Table 1). The cover crop was

Table 2. Effect of August-calving cow-calf system on pregnancy rates by year. Systems were 1) perennial forage and corn residue grazing (PF) or 2) summer drylot, fall cover crop grazing, and corn residue grazing (DC).

	Treatment			
Item	PF	DC	SEM[1]	*P*-value[2]
Pregnancy rate, %				
Year 1	81.5	77.2	4.28	0.48
Year 2	96.4	95.9	2.31	0.87
Year 3	92.4	85.0	3.54	0.16

[1]Average SEM across treatments within each year.

[2]*P*-value for main effect of treatment (PF or DC) within year shown. Treatment by year interaction was not significant ($P = 0.72$). Main effect of treatment not significant ($P = 0.22$).

Table 3. Effect of August-calving cow-calf system on cow and calf performance. Systems were 1) perennial forage and corn residue grazing (PF) or 2) summer drylot, fall cover crop grazing, and corn residue grazing (DC).

	Treatment			
Item	PF	DC	SEM[1]	*P*-value[2]
Year 1				
Cow BCS[3]				
Pre-calving (July)[4]	7.02	5.42	0.060	<0.01
Breeding (October)[5]	6.27	5.42	0.061	<0.01
Post-Weaning (February)	5.45	5.09	0.055	<0.01
Calf BW, lb				
Birth	85.7	86.0	3.91	0.96
Weaning (January)[6]	403	391	4.00	0.03
Year 2				
Cow BCS[3]				
Pre-calving (July)[4]	6.69	6.05	0.059	<0.01
Breeding (October)[5]	6.63	6.10	0.060	<0.01
Post-Weaning (February)	6.34	6.45	0.048	0.12
Calf BW, lb				
Birth	81.8	88.0	3.79	0.25
Weaning (January)[6]	442	466	3.93	<0.01
Year 3				
Cow BCS[3]				
Pre-calving (July)[4]	7.71	7.26	0.059	<0.01
Breeding (October)[5]	6.84	6.84	0.061	0.98
Post-Weaning (February)	5.89	7.13	0.061	<0.01
Calf BW, lb				
Birth	89.5	81.3	3.88	0.14
Post-Weaning (February)[6]	474	482	4.00	0.17

[1]Average SEM across treatments within each time point.

[2]*P*-value for main effect of treatment within time point. 3-way interaction between treatment, time point, and year was significant ($P < 0.01$) for cow BCS and calf BW.

[3]Body condition score (1 = emaciated to 9 = obese).

[4]PF cows grazing perennial forage, DC cows limit-fed in drylot to meet energy requirements.

[5]Body condition prior to bull turn-out for breeding. In Year 1, PF cows placed on stockpiled forage sorghum and DC cows placed on alfalfa/grass pivots. In Year 2, PF cows placed in the drylot and DC cows placed on cover crop. In Year 3, PF cows placed on dormant perennial grass pastures and DC cows placed on cover crop. Breeding season was 44, 46 and 49 d in Years 1 through 3, respectively.

[6]Age of calves at weaning in Year 1 through 3 was 143, 157, and 164 d, respectively.

planted August 27 using the same oat, rye, and rapeseed mix as described in Year 2, and cows grazed cover crop 92 days. Beginning September 22 until cattle were moved to cover crops on November 2, calves were creep fed alfalfa hay as described in Years 1 and 2.

Results

Pregnancy rates did not differ ($P < 0.72$; Table 2) between treatments within year. There was a treatment × time × year interaction ($P < 0.01$) observed for cow BCS and calf BW (Table 3). In Year 1, BCS was greater ($P < 0.01$) at pre-calving (July), breeding (October), and post-weaning (February) time points for PF compared to DC cows; however, cows in the DC treatment never dropped below a BCS 5 and were still considered to be in adequate condition. Differences in BCS between treatments were expected because PF cows could easily gain body condition when they were on summer pasture and not lactating, whereas DC cows were fed to maintain a BCS of 5 while in the drylot. Birth weights of calves were not different ($P = 0.96$) between treatments, with average weight being 86 ± 4 lb. At weaning, however, BW of PF calves was 12 lb greater ($P = 0.03$) than DC calves (403 vs. 391 lb, respectively).

In Year 2, cow BCS was greater ($P < 0.01$) for PF than DC cows at pre-calving and breeding but was not different ($P = 0.12$) between the treatments at weaning. Cows in the DC treatment in Year 2 never fell below a BCS 6. Like Year 1, calf birth 0.25 BW was not statistically different ($P = 0.12$) between PF (81.8 lb) and DC (88.0 lb) groups, but unlike Year 1, weaning weights were greater ($P < 0.01$) for calves in DC compared to PF by 24 lb. The greater weaning weights observed in DC calves may be attributed to the feed resource available to pairs. Prior to breeding, pairs in the DC treatment were in the drylot and PF pairs were on pasture. From breeding until weaning, DC pairs were grazing a high-quality cover crop and pairs in the PF treatment received a TMR in the drylot. It is possible the different quantity and quality of feedstuffs pairs had access to in each system, especially from breeding to weaning, impacted calf performance.

In Year 3, BCS was greater ($P < 0.01$) for PF (7.7) at the pre-calving time point

but was lower ($P < 0.01$) than DC cows at weaning (5.9 vs. 7.1). Cow BCS was not different ($P = 0.98$) between treatments at breeding in October. Body weight of calves at birth and weaning was not different ($P \geq 0.14$) between PF or DC, with average weaning weight across treatment groups being 478 ± 4 lb.

Conclusion

Cow and calf performance were not sacrificed in the semi-confined cow-calf system. Although differences in cow BCS were sometimes observed between the two production systems across years, all cows maintained adequate body condition throughout the study and no differences were observed in pregnancy rates. Based on these performance data, a semi-confined production system combining summer drylotting, fall cover crop grazing, and corn residue grazing could be a viable alternative when perennial forage is limiting but ample cropland is available. However, viability of this system will ultimately depend on costs, which will vary between producers.

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Including Gene Edited Sires in Genetic Evaluations

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Summary with Implications

A simulation study investigated and provided potential solutions to practical issues that could arise from including gene-edited sires in routine genetic evaluations. Gene-editing is a technique for adding, deleting, or replacing nucleotides in the genome. Editing nucleotides controlling important socioeconomic traits (e.g., growth, carcass, disease susceptibility) is expected to improve rates of genetic gain. However, targeted alterations of the genome can affect the relationship among individuals and, consequently, introduce bias in Expected Progeny Differences. The current study illustrated that, indeed, Expected Progeny Differences for the progeny of edited sires were underestimated. Consequently, these animals would be less likely to be selected as parents for subsequent generations. Therefore, if edited sires are introduced into genetic evaluations, the statistical models used in the evaluation need to appropriately accommodate the changes among animals that the targeted gene edits create, and adjusting the kinship among animals is one way to do this. Without accounting for these targeted changes Expected Progeny Differences will be biased, and selection decisions could be made incorrectly.

Introduction

Gene-editing is an emerging technology for adding, deleting, or replacing nucleotides in the genome that offers the potential to increase the frequency of favorable alleles. Although current governmental regulation in the U.S. creates undue burdens for bringing the full potential of this technology to fruition, it is important for genetic evaluation service providers to consider the potential impact of gene-edited animals and their offspring in routine genetic evaluations. This is particularly true when the edits are related to quantitative traits for which Expected Progeny Differences (EPD) exist or traits that are genetically correlated to traits with EPD. It is possible that gene-editing technology could enable large numbers of edits controlling important socioeconomic traits to be performed and, when coupled with genomic selection, could prove a powerful means of improving genetic gain for complex traits. However, genetic evaluations are based on the relationship among individuals, whether through pedigree (numerator relationship, A matrix), marker-based (genomic relationship, G matrix), or a combination of pedigree and genomic relationships (H matrix). Changing nucleotides in the genome can affect these relationships and, consequently, introduce bias in EPD. The objective of this study was to quantify differences in Estimated Breeding Values (EBV; twice an EPD) using an 8-generation simulated beef cattle population that included gene-edited sires and their progeny.

Table 1: Average absolute bias and dispersion of EBV in generation 8 averaged over all relationship matrices, number of gene-edited QTN, and number of gene-edited sires.

Status	Strategy[1]	Average absolute bias	Slope[2]
Progeny of non-gene-edited	Non-weighted	0.79 (0.01)	0.90 (0.06)
Progeny of non-gene-edited	Weighted	0.78 (0.01)	0.95 (0.01)
Progeny of gene-edited	Non-weighted	1.36 (0.50)	0.84 (0.11)
Progeny of gene-edited	Weighted	0.90 (0.14)	0.93 (0.04)

[1]If the relationship matrix was weighted based on the QTN effect (Weighted) or not (Non-weighted);

[2]Slope of the regression of true BV on EBV, representing the dispersion of EBV. The expected value is 1.

Procedure

The simulated genome contained 99 quantitative trait nucleotides (QTN) and 6,000 single nucleotide polymorphisms (SNP) distributed across 3 chromosomes. A moderately heritable trait (h^2=0.4) was simulated. In total, the population consisted of 8 generations and a total of 13,100 animals. After 7 generations, gene-edited sires (n=1, 25, or 50) were introduced. The number of QTN edited (% additive variation controlled by the QTN) was 1 (2%), 3 (5%), or 13 (20%). All scenarios were replicated 15 times. Genetic evaluations were performed using pedigree (A), genomic (G), or combined (H) kinship matrices. Relationships were also weighted (w) based on the proportion of genetic variance explained by the edited QTN. Scenarios were compared based on the accuracy of EBV (correlation of true BV (TBV) and EBV), which reflects the potential re-ranking of individuals, average absolute bias, which reflects the error around the estimation of EBV, and the slope (b_1) of the regression of TBV on EBV, which reflects the dispersion of EBV.

Results

The average absolute bias and EBV dispersion in generation 8 averaged over all relationship matrices, number of edited QTN, and number of gene-edited sires are reported in Table 1.

Overall, the average absolute bias and the degree to which EBV were underdispersed increased as the number of gene-edited sires and edited QTN increased ($P \leq 0.001$). Correspondingly, differences in the average absolute bias and EBV dispersion between the progeny of gene-edited vs. non-gene-edited sires and between weighted vs. non-weighted relationship matrices were greater when more sires or QTN were edited. Estimated Breeding Values of prog-

eny of gene-edited sires were associated ($P \leq 0.001$) with more error (greater average absolute bias) when the evaluation used non-weighted relationship matrices and more than one sire or more than one QTN were edited. Differences in EBV dispersion between weighted vs. non-weighted relationship matrices were significant ($P \leq 0.001$) when 25 or 50 sires were edited, with EBV dispersion from weighted relationship matrices closer to the expected value of 1. In generation 8 (included offspring from gene-edited sires), weighting the relationship matrices increased the accuracy by 3% ($P = 0.003$). Given the EBV of the progeny of gene-edited sires were underestimated, re-ranking of individuals in generation 8 was expected, disfavoring the selection of the progeny of gene-edited sires.

Conclusion

In general, the EBV of the progeny of gene-edited sires were associated with greater error (average absolute bias) and were under-dispersed to a greater degree than the EBV of the progeny of non-gene-edited sires. Weighting the relationship matrices increased the accuracy of EBV when the gene-edited sires were introduced, decreased the average absolute bias, and led to EBV dispersion closer to the expected value of 1. Therefore, when gene-edited parents are included in the genetic evaluations, methods such as weighting the relationship matrices should be considered to avoid biased EPD that could lead to incorrect selection decisions.

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Impact of Planning Horizon Length on Breeding Objectives and Resulting Selection Decisions

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Summary with Implications

The weighting of traits in a selection index depends on varying circumstances that can differ among beef producers (e.g. economic factors, breeding systems). The determination of planning horizon is an additional variable that can differ among producers that represents the impact of genetic selection decisions over a gradient of time. A web-based economic index construction platform (iGENDEC) was used in the current study to investigate the implications of planning horizon on relative emphasis values of traits within the breeding goal and potential differences in sire selection decisions. General-purpose indexes were created for three breeding systems under six different planning horizons (2–50 yrs.). Relative emphasis for weight (weaning or hot carcass) at point of sale decreased while stayability increased as length of the planning horizon increased. The ranking of selection candidates varied as planning horizon and the point of sale changed. The results are indicative of the importance for determining the correct planning horizon when developing selection indexes.

Introduction

Economic selection indexes serve as tools for multiple trait selection to drive genetic selection decisions based on specified breeding objectives with the aim of increasing commercial-level net profit. The development of selection indexes requires defining a breeding objective, determining the economic parameters associated with costs/revenues, assuming a breeding system, and assuming current population (herd) phenotypic means. Generalized indexes (i.e., those published by U.S. beef breed associations) make the above assumptions relying on national averages, and although these tools are the preferred method of practicing sire selection, unique differences exist among beef cattle producers that may deviate from these assumptions. This is particularly true with respect to current phenotypic performance and the length of time that the economic impacts of sire selection decisions should be considered (planning horizon; PH).

Selecting a PH is a complex decision that can often be overlooked when constructing economic selection indexes. Philosophically, planning horizon can be thought of as the length of time (years) that the user wants to consider in determining the economic impact of a genetic selection decision. Using simulation to create a large cowherd that expresses the traits in the breeding objective, as is commonly done in developing selection indexes, PH represents the number of years simulated with the improved genetic merit of bulls. Consequently, PH impacts the number of expressions of traits and thus their economic impact. Additionally, PH interacts with discounted gene flow and discounted expression rates. Discounted gene flow accounts for the fact that sire selection decisions impact future calf crops through the retention of daughters. Discounted expression rates account for the fact that some traits are expressed later in life than others.

Thus, the current study investigated the impacts of varying PH on the relative emphasis values of traits and the ranking of selection candidates based on indexes developed for different market endpoints and for different breeding systems.

Procedure

The economic selection indexes evaluated were created using iGENDEC, a web-based decision support platform that allows for the construction of economic selection indexes for U.S. beef production systems. The general-purpose indexes were created under the assumptions that replacement females were retained. Given this, one index assumed calves would be marketed at weaning and the other assumed retained ownership on all non-replacement animals through the finishing phase. The traits in the indexes for the weaning point of sale included weaning weight-direct (WW-D), weaning weight-maternal (WW-M), mature cow weight (MW), stayability (STAY), heifer pregnancy (HP), calving ease-direct (CE-D), and calving ease-maternal (CE-M). For the finish endpoint index, the traits of hot carcass weight (HCW), ribeye area (REA), fat depth (FAT), marbling score (MS), yearling weight (YW), and feed intake (FI) were included in addition to those in the weaning endpoint index.

Within each index, three breeding systems were assessed: Angus bulls mated to Angus cows, half Simmental and half Angus bulls mated to cows of the same composition, and Simmental bulls mated to half Hereford and half Angus cows. These three breeding systems were chosen to compare the impacts of direct and maternal heterosis as well as reflect a sampling of real-world breeding systems. Six PH (2, 5, 10, 20, 30, and 50 yrs.) were assessed. In total, 36 indexes were developed. In each scenario, the economic parameters (e.g., variable cow costs, value of calves sold, etc.) and the base phenotypic means were the same. Resulting output included marginal economic values (MEV) for each trait in the breeding objective where the MEV is the economic value of changing the trait by one unit while all other traits are held constant. Relative emphasis values were then calculated as the absolute value of the MEV multiplied by the genetic standard deviation for the trait and then divided by the sum of these products for all the traits. The relative emphasis values for each trait are bounded by 0 and 1, and the sum of all relative emphasis values is equal to 1. The relative emphasis values can be interpreted as the relative importance, proportionally, of a trait in the breeding objective.

The indexes were then applied to a group of selection candidates (n=27,123). Spearman rank correlation coefficients were then calculated for all pairwise combinations of indexes to compare the effects of planning horizon, breeding system, and point of sale.

Finally, an evaluation of HCW was conducted to assess the change in relative emphasis as average hot carcass weight increased from 650 lbs. to 1150 lbs. in 100 lb increments when a discount threshold of 1,050 lbs. existed. This was conducted under the purebred Angus system for 2-, 20-, and 50-year planning horizons. This threshold was chosen to represent discounts that exist in U.S. beef production systems.

Table 1. Comparison of relative emphasis values for weaning weight direct (WW-D), hot carcass weight (HCW), and stayability (STAY) for different lengths of planning horizon from indexes that assumed a weaning (Weaning) or finish (Carcass) point of sale.

	Weaning		Carcass	
Planning Horizon, yrs.	WW-D	STAY	HCW	STAY
2	0.859	0.000	0.449	0.002
5	0.586	0.183	0.444	0.016
10	0.434	0.231	0.407	0.062
20	0.324	0.321	0.363	0.160
30	0.282	0.362	0.348	0.190
50	0.259	0.375	0.334	0.219

Results

Relative emphasis values for the primary revenue traits (WW-D and HCW) and STAY were averaged over all breeding systems and are reported in Table 1. As planning horizon increased in indexes that assumed a weaning point of sale, the relative emphasis shifted from WW-D to STAY with the largest change observed between 2- and 5-year PH followed by more gradual changes beyond 5 yrs. Likewise, given the finishing point of sale, the relative emphasis of HCW steadily declined and STAY increased as PH increased. At the longer PH (30 or 50 yr.), the changes in relative emphasis for these traits became smaller and began to plateau.

The Spearman's rank correlation coefficients suggested little re-ranking of the selection candidates based on differences in assumed breeding systems if the point of sale and PH were the same (r=0.96 ± 0.04). The average rank correlation coefficients between indexes with different endpoints was r=0.71 ± 0.12 when averaged over breeding system and PH lengths. When indexes assumed a finish endpoint, substantial re-ranking (r=0.78 ± 0.09) was observed between the short PH (2, 5, and 10 yrs.) and the longer PH (20, 30, and 50 yrs.). However, given a weaning point of sale, changes in rank correlations were less extreme.

For all PH, as the herd average HCW approached the discount threshold, the relative emphasis of HCW decreased. As planning horizon increased, the relative emphasis of HCW also decreased.

Conclusions

Results from the current study illustrate that situational differences among cattle enterprises can manifest in differences in appropriate selection indexes. The relative emphasis values provide a sense for which traits are economic drivers of a breeding objective. The changes in relative emphasis values reported herein demonstrate the potential sensitivity to assumptions of planning horizon length. Such changes in planning horizon length might be determined by short-term needs for revenue. The current study also illustrated that differences in planning horizon length and sale point of calves can lead to differences in the ranking of bulls. Producers who make changes to their operational goals also need to update the criteria they use to select bulls, including the relative emphasis that they place on those criteria. Differences in current levels of phenotypic performance can also impact the importance of traits in breeding objectives and ultimately selection indexes as illustrated by changes in average hot carcass weight.

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Effect of Increasing Energy 30 days Prior to Artificial Insemination in Beef Heifers

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Summary with Implications

A 3-yr study utilized 300 Angus-based, spring-born heifers to evaluate postweaning heifer development systems on gain and reproductive performance. Three groups of heifers were developed over the winter development period either grazing winter range or fed a dry lot diet targeted to 1.5 lb/d of gain in order to achieve 65% of their mature body weight at breeding. Thirty days prior to artificial insemination, heifers grazing winter range entered the dry lot and were fed this same diet, one group of dry lot heifers remained on this diet, and the other received increased energy in the form of wet corn gluten feed. Post development body weight and average daily gain were greater among dry lot developed heifers. There were no differences in artificial insemination or final pregnancy rate. Results indicate that producers may use a 30-day increase in energy prior to artificial insemination to decrease overall development inputs in range heifers without compromising reproductive efficiency when compared to dry lot heifers receiving greater inputs.

Introduction

Heifer development represents one of the greatest costs for cow/calf producers other than the actual feed costs. The goal of this study was to investigate production systems that allow for lower inputs and cost without compromising lifelong reproductive success. A previous study (*2017 Nebraska Beef Cattle Report*, pp. 5–7) evaluated body weights (BW), average daily gain (ADG), and reproductive efficiency in heifers developed for approximately 160 days on four different treatments 1) corn residue & range, 2) winter range, 3) dry lot low (12% wet corn gluten feed (DM basis)), and 4) dry lot high (21% wet corn gluten feed (DM basis)). Despite dry lot heifers being on higher energy diets throughout their development period, no differences were seen in artificial insemination (AI) or final pregnancy rate. While it is understood that an increase in plane of nutrition and body condition at critical timepoints promotes cyclicity, puberty attainment, and lifelong reproductive efficiency, the minimum threshold of inputs to acquire optimal pregnancy rates and development of productive cows is less clear. Furthermore, compensatory gain and grazing behavior also contribute to a heifer's ability to achieve puberty and become pregnant in a timely manner. Therefore, objectives of this study were to evaluate the impact of increased energy 30 days prior to AI on BW, ADG, and pregnancy rates among heifers developed on range and in a dry lot.

Procedure

Heifer Development

A 3-yr study utilized Angus crossbred heifers (n= 100/yr) at the West Central Research and Extension Center in North Platte, NE. Heifers were blocked by BW and randomly assigned to 1 of 3 groups. During the winter development period (average 131 ± 3.5 d/yr) heifers were assigned to either upland range (RANGE) or fed a similar dry lot diet in two pens with a targeted gain of 1.5 lb/d in order to achieve 65% of their mature BW (14 lb/hd/d hay, 5 lb/hd/d wet corn gluten feed [WCGF], and 0.75 lb/hd/d supplement). Thirty days prior to AI, one dry lot group remained on this diet (DLLO) while the other (DLHI) received an additional 9 lb/hd/d WCGF (14 lb/hd/d hay, 14 lb/hd/d wet corn gluten feed [WCGF], and 0.75 lb/hd/d supplement). Heifers developed on RANGE grazed winter range and received the equivalent of 1 lb/hd/d of a 29 % crude protein (CP), dried distillers' grain-based pellet containing monensin until 30 days prior to AI where they entered the dry lot and received the DLLO diet. Average diet composition and nutrient analysis for the 30-day diets prior to AI are presented in Table 1.

As described in a previous study (*2017 Nebraska Beef Cattle Report*, pp. 5–7), all heifers were synchronized with the melengestrol acetate- prostaglandin F2α (MGA-PG) protocol. Heat detection aids (Estrotect™, Rockway Inc., Spring Valley, WI) were applied at the time of PG injection (Lutalyse, Zoetis, Florham Park, NJ). Heifers exhibiting standing estrus were AI 12 hours later. Heifers were placed with bulls 10 days following AI on native upland range at a 1:50 bull to heifer ratio for a 60-day breeding period. Those heifers that did not express estrus within 6 days following the first PG injection were recorded and given a second PG injection, and then immediately placed with bulls. Pregnancy diagnosis was conducted via transrectal ultrasonography (ReproScan, Beaverton, OR) 45 days following AI. Forty-five days after the bulls were removed a second pregnancy diagnosis determined final pregnancy rate.

Statistical Analysis

All analyses were conducted using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary NC). The model statement used contained the effects of treatment group and year. Treatment group within year was considered the experimental unit, with Year and Treatment treated as categorical variables. Response variables include BW recorded throughout the study, ADG during each phase of the study, pregnancy rate to AI, and final pregnancy rate. Response variables related to weight were assumed to follow a normal distribution, while response variables related to pregnancy were treated as binomial. A P-value ≤ 0.05 was considered significant. A P-value ≤ 0.10 was considered a tendency.

Table 1. Dry lot diets during the 30-day treatment period (DM Basis)

Item	RANGE[1], DLLO[2]	DLHI[3]
Ingredient %		
Hay	76.71	57.24
Wet Corn Gluten Feed	18.90	39.49
Heifer Supplement[4]	4.37	3.26
Nutrient Analysis %		
DM	78.35	72.13
CP	12.84	15.42
TDN	62.18	70.56

[1]RANGE heifers were offered the equivalent of 1 lb/hd/d of 29% CP cake while grazing winter range 131 ± 3.5d/yr until they were moved into the dry lot 30-days prior to AI and received 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement.

[2]DLLO heifers were developed in the dry lot 131 ± 3.5d/yr and continued through estrous synchronization and AI receiving 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement.

[3]DLHI heifers were developed in the dry lot 131 ± 3.5d/yr receiving 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement diet until 30 days prior to AI where they then received an additional 9 lb/h/d of WCGF.

[4]Supplement = dry rolled corn (81.35% of supplement, (DM basis)), limestone (11.11%), iodized salt (5.55%), trace mix (1.39%), Rumensin- 90 (0.37%), and Vitamins A- D- E (0.22%).

Table 2. Effect of 30-day increase in energy on gain and reproductive performance

Item	RANGE[1]	DLLO[2]	DLHI[3]	SEM	*P*-value
n[4]	3	3	3		
Initial BW, lb	483	482	483	0.38	0.20
Post Development BW[5], lb	635[b]	743[a]	741[a]	9.19	0.01
Development ADG[6], lb	0.57[b]	1.42[a]	1.40[a]	0.09	0.02
Prebreeding BW, lb	688[b]	801[a]	828[a]	4.30	<0.01
Percent of mature BW[7], %	57[b]	66[a]	68[a]	0.004	<0.01
Synchronization ADG[8], lb	1.49	1.66	2.49	0.16	0.12
AI pregnancy diagnosis BW, lb	773[b]	850[a]	872[a]	3.71	<0.01
Final pregnancy diagnosis BW, lb	911[b]	973[a]	987[a]	2.98	<0.01
Breeding ADG[9], lb	1.45[b]	0.83[a]	0.78[a]	0.02	<0.01
AI pregnancy, %	49	63	69	0.06	0.43
Final pregnancy, %	85	95	96	0.02	0.09
Calving rate[10], %	77	92	90	0.04	0.12
Calved in first 21 d, %	41	42	61	0.12	0.12

[1]RANGE heifers were offered the equivalent of 1 lb/hd/d of 29% CP cake while grazing winter range 131 ± 3.5d/yr until they were moved into the dry lot 30-days prior to AI and received 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement.

[2]DLLO heifers were developed in the dry lot 131 ± 3.5d/yr and continued through estrous synchronization and AI receiving 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement.

[3]DLHI heifers were developed in the dry lot 131 ± 3.5d/yr receiving 14 lb/hd/d hay, 5 lb/hd/d WCGF, and 0.75 lb/hd/d supplement diet until 30 days prior to AI where they then received an additional 9 lb/h/d of WCGF.

[4] Represents number of replications; 1 yr = 1 replication.

[5]BW prior to the 30-day treatment period.

[6]ADG during the 131-day development period.

[7]Percent of mature BW at breeding based on mature cow size of 1200 lb.

[8]ADG between synchronization and breeding.

[9]ADG between prebreeding and first pregnancy diagnosis.

[10]Percent of heifers that calved.

[a, b] Means in a row with different superscripts are different ($P \leq 0.05$)

Results

Heifer ADG in DLLO and DLHI were greater ($P = 0.02$ and $P = 0.03$ respectively) than RANGE during the development period, but there were no differences observed in ADG during the 30-day treatment period between DLHI, DLLO, and RANGE (Table 2). Pre-breeding BW was greater ($P < 0.01$) for DLHI and DLLO compared to RANGE; however, breeding ADG (the time period between pre-breeding and first pregnancy diagnosis) was greater ($P < 0.01$) for RANGE compared to DLHI and DLLO. This may be attributed to compensatory gain and grazing behavior differences in the heifers developed on range. There were no differences in pregnancy rates to AI between DLHI (69%), DLLO (63%), or RANGE (49%). There were also no differences between final pregnancy rates between DLHI (96%) and DLLO (95%) or RANGE (85%). No differences were observed in calving rate or heifers calving in the first 21days.

Conclusion

Ultimately, greater dietary protein and energy for DLHI and DLLO heifers led to greater BW, ADG, but overall short-term nutritional change had no detectable impact on AI conception nor final pregnancy rates across heifer development systems. A greater number of heifers may lead to statistical differences in AI conception, but no differences can be concluded in the current study. When evaluating the best plan for developing heifers, this data may encourage producers to evaluate current development systems and develop heifers on range or decrease the time spent in a dry lot compared to supplying greater inputs throughout the development period. Rather than advocating one of the three systems illustrated over another, the current study illustrates that instead of developing heifers on a high energy diet throughout the winter development period, inputs and cost may be lowered by increasing dietary protein and energy to beef heifers 30 days prior

to AI without compromising long-term reproductive efficiency. An economic analysis evaluating the savings associated with lower inputs compared to lower pregnancy in heifers developed on range is needed to make more accurate heifer development decisions.

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Extending Melengestrol Acetate Treatment from Fourteen to Eighteen Days in Beef Heifers

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Summary with Implications

This study compared estrus synchronization, estrus response, and artificial insemination pregnancy rates of beef heifers fed melengestrol acetate the normal 14-day period or extended to an 18-day period using the melengestrol acetate—prostaglandin—heat detect and timed artificial insemination protocol. Therefore, the purpose of this study was to evaluate if extending melengestrol acetate feeding by 4 days increases the number of heifers ovulating, which would result in greater estrus response and pregnancy rate in the whole herd. Early estrus response following prostaglandin administration occurred in heifers who averaged an earlier estrus response after melengestrol acetate withdrawal but extending the melengestrol acetate feeding period did not increase herd estrus synchronization, estrus response, or pregnancy rate. When necessary, producers may consider extending melengestrol acetate feeding an alternative option without significant differences in pregnancy rate (i.e.: scheduling conflicts).

Introduction

There are two long-term progestin-based protocols for synchronization of estrus: the 14-day (d) controlled internal drug release (CIDR) protocol, and the 14-d melengestrol acetate (MGA) protocol. Synchrony of estrus and subsequent ovulation after administration of prostaglandin F_{2a} (PG) stems from the initial synchronized estrus that occurs following exogenous progestin exposure earlier in the treatment schedule. Long-term progestin-based protocols have gained wide acceptance in development programs for beef heifers due to their effectiveness among both pubertal and peripubertal heifers. Peripubertal heifers, who will ovulate for the first time after progestin withdrawal, often ovulate later following progestin withdrawal leading to decreased synchronization with the herd, estrus response after PG, and pregnancy rates. Pubertal heifers would not ovulate as long as progestin treatment continued.

A previous study comparing 18-d CIDR and 14-d CIDR protocols suggests there are no differences in estrus expression or pregnancy rate due to treatment. It remains conceivable that an extension of MGA feeding would be more impactful due to the differences in estrus response resulting from MGA and CIDR withdrawal. The objective was to determine if increasing the length of MGA treatment would alter the proportion of heifers that express estrus during the estrus detection period following administration of PG and result in increased conception rates to artificial insemination (AI).

Procedure

Black Angus, Black Angus x Simmental, and Red Angus x Simmental crossbred spring calving heifers from two separate herds were transported to a ranch near Sutherland, Nebraska for breeding. Treatments were initiated in April of 2020 (Year-1; 898 heifers) and 2021 (Year-2; 822 heifers). Heifers were separated by herd and allocated into feedlot pens at random containing an average of 111 ± 25 heifers. Each year, pens were assigned to one of two estrus synchronization protocols in an independent measures design for a total of 15 pens. The heifers assigned to the **E14** treatment were synchronized using the 14 d melengestrol acetate (MGA) protocol described in Figure 1 and served as the control group (n = 907). The heifers assigned to the **E18** treatment was similar except the MGA fed during the treatment phase started four days before the initial 14 d treatment period starting on Day -3 (n = 813). The E18 treatment served as the test group.

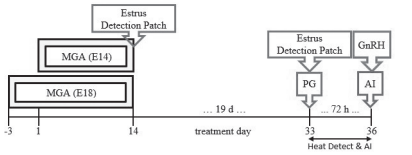

Figure 1. Melengesterol acetate (MGA)—prostaglandin F2α (PG)—gonadotropin releasing hormone (GnRH) protocol used for estrus synchronization in beef heifers. MGA is fed Day 1 to 14 (E14) or Day -3 to 14 (E18). An estrus detection patch is applied following MGA withdrawal in 2021. PG is injected on Day 33 and another estrus detection patch is applied. Heifers are heat detected and AI before Day 36 with the remaining heifers heat detected, AI, and GnRH on Day 36.

On Day 1 or -3 of the protocol, MGA was mixed into the total mixed ration as prescribed at 0.5 mg per heifer per day. On day 15, MGA was withdrawn from the diet. On Day 33, 2cc prostaglandin $F2_{\alpha}$ (PG, Lutalyse® HighCon) was intramuscularly injected, weights were recorded, and estrus detection patches (Estrotect™) were applied. Every 12 hours (h) after PG administration heifers with more than 50% patch removed were AI in the PM. On Day 36, all remaining heifers were AI, as part of the timed AI protocol, and patch scores were recorded (1 = < 25% removed, 2 = 25% to 50% removed, 3 = > 50% removed, 4 = patch missing). Heifers with a patch score of 1 or 2 were not considered to be in estrus, and patch scores of 3 or 4 were considered to be in estrus. Gonadotropin-releasing hormone (Factrel®, GnRH) was intramuscularly injected (2cc) to all heifers with a patch score of 1, 2, or 4. Intact bulls were introduced to both herds 3 days after AI at a heifer to bull ratio of 25:1 and remained with the herd for 30 d. After insemination, heifers grazed on pasture for the remainder of the study. A veterinarian diagnosed pregnancy via transrectal ultrasonography. Pregnancy diagnosis was recorded based on the age of the fetus using

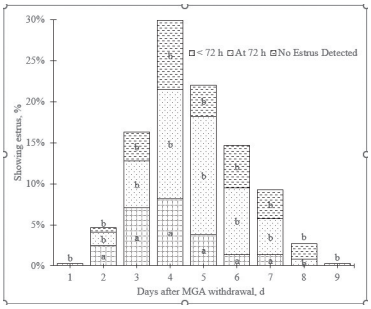

Figure 2. Timing of estrus expression after melengestrol acetate (MGA) withdrawal separated by timing of estrus expression after prostaglandin (PG) administration. '< 72 h' denotes estrus expression before 72 h after PG administration, 'At 72 h' denotes estrus expression 72 h after PG administration. [a,b] Different superscripts have different average timing of estrus after MGA withdrawal based on individual timing of estrus after PG administration

Table 1. Differences in estrus detection after melengestrol acetate (MGA) withdrawal and prostaglandin (PG) administration, conception rate, and weight gain with both years of treatment separated by herd, expressed as least square means and standard error of the mean.

		Treatments		
		E14[1]	E18[2]	P value
Herd 1, (n = 898)	Avg MGA Estrus Time[3], d	5.0 ± 0.24	4.5 ± 0.23	0.12
	Avg PG Estrus Time[4], h	68 ± 1.1	67 ± 1.1	0.31
	Exhibiting Estrus, %	67 ± 4.0	67 ± 4.0	0.96
	Pregnancy Rate, %	56 ± 2.4	57 ± 2.4	0.69
	Avg Daily Gain, lb	1.4 ± 0.37	1.4 ± 0.37	0.73
Herd 2, (n = 822)	Avg MGA Estrus Time[3], d	4.6 ± 0.11	4.6 ± 0.16	0.82
	Avg PG Estrus Time[4], h	61 ± 1.7	62 ± 1.7	0.15
	Exhibiting Estrus, %	75 ± 9.3	77 ± 9.5	0.65
	Pregnancy Rate, %	60 ± 4.5	58 ± 4.7	0.69
	Avg Daily Gain, lb	1.2 ± 0.22	1.3 ± 0.23	0.50
Both Herds (n= 1720)	Avg MGA Estrus Time[3], d	4.8 ± 0.13	4.5 ± 0.15	0.15
	Avg PG Estrus Time[4], h	64 ± 1.5	64 ± 1.6	0.98
	Exhibiting Estrus, %	71 ± 3.8	73 ± 4.0	0.84
	Pregnancy Rate, %	58 ± 2.3	58 ± 2.4	0.96
	Avg Daily Gain, lb	1.3 ± 0.14	1.4 ± 0.15	0.70

[1]E14 treatment: the normal 14 d MGA estrus synchronization protocol where estrus is exhibited following MGA withdrawal and again after PG administration

[2]E18 treatment: an extended 18 d MGA estrus synchronization protocol where estrus is exhibited following MGA withdrawal and again after PG administration

[3]Average time period between MGA withdrawal and the expression of estrus during Year-2 only

[4]Average time period between PG administration and the expression of estrus

a 7 d window to differentiate pregnancies resulting from AI and natural bull breeding. For the purposes of this study, only heifers that were recorded as artificially inseminated were considered pregnant and the remainder were considered open. A few heifers from each treatment may have been bull bred if fetal aging was indeterminable around the time of AI.

Protocol Changes in Year 2

On Day 15 (1 d following MGA withdrawal), estrus detection patches were applied, and twice daily reports of heifers with more than 50% patch removed were recorded. The following changes in the protocol were management decisions made by the producers in the second year of the experiment. After PG administration, heifers from both herds with more than 50% patch removed were recorded at 48 h and one pen from each treatment in herd 1 were recorded at 60 h. All heifers from herd 2 were administered GnRH regardless of patch score. No bulls were introduced to herd 1 after PG, which means all pregnant heifers from herd 1 were bred by AI in the second year of this study. Pregnancy diagnosis was confirmed 72 d after AI in herd 2 and 51 d after AI in herd 1.

Statistical Analysis

Statistical analyses were performed using SAS 9.4 (SAS Institute Inc.) via the LSMEANS in the GLIMMIX procedure. Estrus timing and responses after MGA withdrawal and PG administration, pregnancy status, and average daily gain (ADG) from AI to pregnancy diagnosis were analyzed as responses to treatment as a fixed affect. Timing of estrus after MGA withdrawal was further analyzed as a response to timing of PG administration induced estrus. Estrus timing and responses after MGA withdrawal and PG administration, pregnancy status, and ADG from AI to pregnancy diagnosis were analyzed as a response to herd. The experimental unit was 'pen' by 'year'.

Results

Estrus detection after MGA withdrawal precedes estrus response after PG administration but was only documented in Year-2 of the study. Melengestrol acetate induced estrus was detected in 50% of E14 and 46% of E18 with a normal distribution over a 9-d period but was not different between treatments (P = 0.60). The timing of estrus detection after MGA withdrawal was not different between treatments (P = 0.15, Table 1). Heifers who demonstrated behavioral estrus earlier after MGA withdrawal also exhibited estrus earlier (48 h or 60 h) after PG administration with differences between early behavioral estrus and estrus or non-estrus exhibiting heifers at timed-AI (P < 0.01, Figure 2). The timing of estrus after MGA withdrawal averaged 0.55 d earlier for heifers who displayed estrus after PG administration (P < 0.01) and 0.98 d earlier for heifers who displayed early estrus after PG administration but was not different by treatment (Table 1). As such, heifers that exhibited estrus after MGA withdrawal were more likely to exhibit estrus again after PG administration (P < 0.01) but were not different by treatment (P = 0.63). These differences suggest the timing of estrus after MGA withdrawal is paralleled with estrus after PG administration but extending the MGA treatment period from 14 d to 18 d did not impact when and if heifers exhibit estrus in the final stages of the synchronization and insemination process. The natural variance of cyclicity in individual heifers makes predicting estrus timing difficult, but parallel behavior among group averages suggest similar timing of estrus after MGA

withdrawal and PG administration for this protocol.

In Year-1, the timing of PG-induced estrus averaged 64 ± 2.4 h for E14 and 63 ± 2.4 h for E18. In Year-2, the timing of PG-induced estrus averaged 65 ± 1.6 h for E14 and 67 ± 1.8 h for E18. The Year-1 records of PG-induced estrus are a more accurate representation of estrus timing, but neither Year-1, Year-2, or both years combined show differences by treatment ($P \geq 0.47$, Table 1). As such, PG induced estrus expression was not different by treatment ($P = 0.84$, Table 1). There was a greater percentage of heifers in estrus from each treatment in 2020 (E14 = 77.0% and E18 = 72.0%) compared to 2021 (E14 = 65.6% and E18 = 73.0%). Although the percentage of heifers in estrus tended to be different by treatment in 2021 ($P = 0.09$), all these values are within the normal range when compared to previous studies, which suggests the small differences found in this study were not an effect of treatment.

Similar to estrus response, a greater percentage of heifers from both treatments became pregnant in 2020 (E14 = 61.5% and E18 = 58.0%) compared to 2021 (E14 = 53.9% and E18 = 58.2%), but these values are within the normal range of pregnancy rate for AI. In both years combined, treatment did not affect AI pregnancy rate ($P = 0.96$, Table 1). Average daily gain between AI and pregnancy diagnosis were not affected by treatment (Table 1).

While management practices of both herds were the same, some differences in heifer development are expected due to environment, resulting in different rates of puberty, estrus, and pregnancy. These differences did not have an impact on the results of this study, however (Table 1).

Conclusion

Increasing the number of days that MGA was fed to heifers did not affect estrus expression or pregnancy rates resulting from AI but could be an alternative treatment period when necessary (i.e.: scheduling conflicts). The timing of estrus following MGA withdrawal appears to be an indicator of timing of estrus after PG administration, which could be inherent to the normal cyclicity of estrous in cattle using the MGA-AI protocol. More research with pubertal and peripubertal heifers may be required to track timing of estrus after MGA withdrawal and connect it to timing of estrus after PG administration. Further research to investigate synchronization of pubertal and peripubertal individuals is warranted, but the effect of extended progestin treatment on herd synchrony of estrus and pregnancy rate is negligible.

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Artificial Insemination of Beef Heifers with Multi-Sire Sexed Semen

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Summary with Implications

This study observed pregnancy outcomes resulting from artificial insemination of beef heifers with multi-sire sexed semen. It was hypothesized, pregnancy rates resulting from multi-sire sexed semen would be increased compared to pregnancy rates from prior studies using single-sire sexed semen. Producers looking to maximize the proportion of calves of one sex may consider this technique. Ultrasound determined pregnancy rate of heifers given multi-sire sexed semen was 65%, which is 12% greater than the average pregnancy rate reported in previous studies using single-sire sexed semen. After accounting for date of birth however, the adjusted AI conception rate was calculated to range between 55 and 62% with a calving rate between 51 and 57%. In summary, multiple sires may outperform single sires' pregnancy rate to artificial insemination with sexed semen.

Introduction

Multi-sire (aka. heterospermic or sperm pack) semen is rarely used for artificial insemination (AI) when assignment of calves' paternity is important, and the value of genotyping is too low. However, previous studies have shown pregnancy success increased 11—13% in heifers using multi-sire semen.

Sexed semen has been available for many years, but it has only recently become cost-effective for commercial producers. There are still challenges associated with utilizing sexed semen because it requires a more intensive protocol. Normal viability of conventional semen is >24 h following deposition, while the period of viability for sexed semen is generally considered to be much shorter. Due to differences among bulls, length of viability, reduced quantity of sperm per unit of sexed semen, and the timing of peak ovum viability, pregnancy rates are decreased among heifers not exhibiting estrus at the time of AI, particularly when sexed semen is used.

Bull semen resiliency can vary due to sorting and subsequent cryopreservation, and thus exhibit varied viability of sexed sperm cells post-deposition. A mixture of semen from multiple bulls in a semen straw may increase fertility and/or provide a longer period of optimal viability than that of an individual bull.

Figure 1. Spit-Time AI: Melengestrol acetate (MGA)—prostaglandin F2α (PG) protocol used for estrus synchronization in beef heifers. MGA is fed from Day 1 to 14 and PG is administered on Day 33 along with an estrus detection aid. Heifers exhibiting estrus by Day 36 or 37 are AI. All remaining heifers are administered gonadotropin releasing hormone and AI.

Procedure

Twelve, unproven 5-way cross two year old bulls, born and raised on a ranch outside Imperial Nebraska were sent to ORIgen Inc. (Huntley, MT) for collection of semen. Bulls passed a breeding soundness exam and sperm passed post thaw evaluation. Sperm cells from three sires were pooled together in equal proportions and sexed (SexedULTRA4M) to favor female progeny with an expected 85–90% heifers and 15–10% bulls, forming four groups of multi-sire sexed semen straws (labeled: A, B, C, and D). Summer calving crossbred composite beef heifers (n=937) raised on the same ranch were transported to a feedlot on the ranch for estrus synchronization in June 2021. All heifers were assigned to the melengestrol acetate (MGA)—prostaglandin F_{2a} (PG) protocol for split-time AI (Figure 1). In this protocol, MGA was mixed into a total ration from Day 1–14 and PG was administered on Day 33 along with an estrus detection aid. Heifers exhibiting estrus by Day 36 or 37 are AI. There were 841 heifers retained through the study: 706 AI with multi-sire sexed semen and 135 AI with conventional semen.

Heifers were estimated to weigh approximately 625 lb at feedlot entry and 725 lb at AI. At PG administration (2cc estroPLAN®), estrus detection patches (Estrotect™) were placed on the tail head. Patches were scored at AI (1 = < 25% removed, 2 = 25%—50% removed, 3 = > 50% removed, 4 = patch missing) with patch scores of 3 and 4 considered to be in estrus. Heifers exhibiting estrus after PG administration were removed from the herd at 72 h and 96 h for AI using the multi-sire sexed semen. Forty straws of semen from each sire group were administered in series to improve randomization of AI among heifers. Immediately following multi-sire sexed semen AI, the remaining heifers not previously removed from the herd by 96 h were administered 2cc Fertagyl (gonadotropin-releasing hormone) and artificially inseminated using conventional semen from proven sires unrelated to the original sires. Heifers sorted for exhibiting estrus could have been exhibiting estrus for 3–24 h before AI. Each day after AI, inseminated heifers were transported to pasture and placed with unrelated unproven bulls for a 60 d breeding season at heifer to bull ratio of 25:1.

At 101 d after timed-AI, pregnancy status was determined via transrectal ultrasonography, and fetal size determined age

of the fetus. Based on fetal age, pregnant multi-sire sexed semen AI heifers were sorted into one of three groups: 1) 'EARLY' (80–101 d post AI; n = 457), 2) 'MIDDLE' (70–79 d post AI; n = 56), and 3) 'LATE' (<70 d post AI; n = 128). At birth, progeny sex and date of birth (DOB) were recorded. Heifers from the 'MIDDLE' and 'LATE' groups were not considered at parturition.

At parturition, calving rate was calculated based on the number of calves born from the EARLY group divided by the number of heifers administered multi-sire sexed semen. An adjusted conception rate was calculated based on the percentage of calves born in the EARLY group on each DOB multiplied by the number of heifers observed pregnant through ultrasound divided by the total number of heifers who received multi-sire sexed semen in order to account for heifers who lost their calf after pregnancy check. Heifer to bull rate was calculated by dividing the number of heifer calves born by the total number of calves born and was expected to approach 85–90% among heifers successfully bred by multi-sire sexed semen. Adjusted conception rate, calving rate, and heifer to bull rate were calculated for each DOB. The earliest DOB where heifer to bull rate equaled 85–90% was considered the last day heifers bred by multi-sire sexed semen would give birth, which ranged from 295–300 d post AI. Based on a DOB between 295 d and 300 d, a range for adjusted pregnancy rate and calving rate were assumed. In these calculations, twins were counted as one calf but were not considered as part of the heifer to bull rate. A control treatment was not used in this study and observations were compared to prior studies using single sire sexed semen.

Results

This observational study observed 87% of heifers expressed estrus with 83% inseminated with sexed semen and 4% inseminated with conventional semen. Sixty-four percent of heifers exhibited estrus by 72 h and 22% exhibited estrus between 72 h and 96 h. According to the protocol, 74% of heifers should exhibit estrus by 72 h and an additional 14% by 96 h totaling 88%, which suggests the estrus response was normal in the current study.

Table 1. Pregnancy results of heifers inseminated with conventional and sexed semen or bull bred by multi-sire groups and expected time of pregnancy.

	n	OPEN[1], %	EARLY[2], %	Adj[3], %	MIDDLE[4], %	LATE[5], %
Sexed	706	9	65	55–62	8	18
Sire group A	197	9	62	50–57	10	19
Sire group B	176	11	69	56–66	6	14
Sire group C	187	5	69	63–68	8	18
Sire group D	146	12	58	50–54	8	23
Conventional	135	20	49		6	25

[1]Open: Pregnancy was not observed through ultrasound after AI and a 60-day breeding period.

[2]EARLY: Fetal age was observed through ultrasound to be between 80 and 101 d post AI.

[3]Adjusted pregnancy rate was calculated based on the percentage of 'EARLY' calves born Day 295–300 post AI multiplied by the number of heifers observed pregnant through ultrasound to multi-sire sexed semen divided by the total number of heifers who received multi-sire sexed semen.

[4]MIDDLE: Fetal age was observed through ultrasound to be between 70 and 79 d post AI.

[5]LATE: Fetal age was observed through ultrasound to be less than 70 d post AI.

Overall pregnancy rate was 89% with 61% 'EARLY', 8% 'MIDDLE, and 19% 'LATE'. Within the 'EARLY' group, multi-sire sexed semen heifers had 65% pregnancy success and conventional semen heifers had 49% during the same time period (Table 1). Pregnancy rates of 53% have been reported in other studies utilizing single-sire sexed semen administered to heifers exhibiting estrus. The expected success rate of conventional semen on heifers not exhibiting estrus could be as low as 22%, but this does not account for the 4% of heifers that were exhibiting estrus and given conventional semen or the 20 day window in which some may have exhibited estrus later and been bred naturally by bulls in the pasture.

The four multi-sire groups had differing rates of success ranging from 58% to 69% (Table 1). Conventional sire success was combined due to much wider ranges of success between individual sires with low numbers of individual inseminations on heifers in various stages of their estrous cycle (Table 1). It is hypothesized the variability between sire groups may be a result of the viability of some individuals that make up that sire group or the random assignment of heifers. Given the 20–21 day window for the 'EARLY' group, some heifers may have been bull bred immediately or completed another estrous cycle before being bull bred 18–24 d later, resulting in a much later DOB. It is equally likely that heifers completing another estrous cycle after the end of the synchronization protocol would be successfully bull bred at the 'MIDDLE' time period. Any heifers that failed to retain a fertilized egg would have had the highest chance of re-fertilization by the 'LATE' time period. Despite the potential for sire misassignment, multi-sire sexed semen performed better than is normally expected from sexed semen, but scientific research is required to make these conclusions.

Separation of AI and bull bred heifers within the EARLY group was calculated using DOB and the accepted heifer to bull rate of 85–90% to informally attribute parentage, a concept that does not directly negate the aforementioned pregnancy results. Based on these rates it was assumed the heifers bred by multi-sire sexed semen gave birth by Day 295–300 post AI and all other calves born after this period were considered bull bred. During this period the calving rate ranged from 51–57%. Due to calf loss at or before calving, an adjusted pregnancy rate to AI was calculated based on the number of calves born and the number of heifers observed pregnant through ultrasound. Between Days 295 and 300 post AI, the adjusted pregnancy rate to AI ranged from 55–62%. The expected value of 53% for pregnancy rate to single-sire sexed semen is below this range, which suggests multi-sire sexed semen may have outperformed single-sire sexed semen in other studies. Adjusted pregnancy rate among each sire group (Table 1) was decreased. One sire group adjusted pregnancy rate ranged from 63–68%, but it is unknown if this is due to random chance or the sires that make up this group. In either scenario, the relationship between pregnancy rate

and parentage to AI with multi-sire sexed semen requires more research.

Conclusion

When the sex of the calf produced from a mating is an economically relevant consideration (e.g.: replacement heifers or seedstock), there may be value associated with the use of sexed semen. However, adoption of these technologies may be reduced due to variable pregnancy outcomes with sexed semen. Pregnancy rate determined by ultrasound suggests a 12% improvement compared to prior studies and pregnancy rate based on DOB suggests an improvement of as much as 9%. Results from the current study suggest sexed semen from 3 sires pooled together may have outperformed single sire sexed semen when heifers exhibiting estrus are inseminated during an MGA-PG split-time AI protocol. However, further observations will be needed to validate this technique and increase adoption.

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Timing of Implant Use in the Backgrounding System

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Summary with Implications

A two-year study utilized 240 weaned steers each year in a 3-phase yearling production system: winter backgrounding, summer grazing, and finishing. The objective of the study was to determine the effects of winter rate of gain (LOW or HIGH) and implant strategy during the winter backgrounding and summer grazing periods on compensatory gain, animal performance, and carcass characteristics. Calves received 1 of 3 implant strategies: NONE, SINGLE (Revalor-G during summer grazing), and MULTIPLE (Ralgro during winter backgrounding and Revalor-G during summer grazing). All cattle received a Revalor-XS during the finishing phase. Implant strategy and rate of gain during the winter backgrounding phase had additive effects to increase animal performance through all phases. When cattle were backgrounded at a LOW rate of gain, an additional 28 lb of hot carcass weight was attributed to Revalor-G. When cattle were backgrounded at a high rate of gain, an additional 32 lb of hot carcass weight was attributed to Ralgro. Combining the MULTIPLE implant strategy and HIGH rate of gain during winter backgrounding resulted in 75 lb of additional hot carcass weight.

Introduction

Backgrounding strategies can impact animal performance in subsequent phases of production as well as carcass characteristics at harvest. Implanting techniques and targeting a specific rate of gain are key tools used in backgrounding systems to influence gains and economic returns. Calves winter backgrounded at a LOW rate of gain are often observed to have a greater average daily gain (ADG) during the summer grazing phase than calves winter backgrounded at a HIGH rate of gain; thus, demonstrating that the cattle supplemented LOW in the winter compensated in body weight (BW) during the summer phase to cattle supplemented at HIGH during the winter phase (Gillespie-Lewis, 2014 pages 36–38). However, cattle supplemented at a HIGH rate of gain enter the summer grazing phase with a greater BW and often have greater EBW at the end of grazing compared to calves backgrounded during the winter at a LOW rate of gain. This compensatory gain can be economically advantageous by reducing supplementation costs; however, it does not yield the greatest BW so it is important to consider the trade off between compensatory gain and maximizing yield as well as economics when determining a winter supplementation program. Implants are known to increase ADG and BW within each phase of production, but the interactions of implant use during backgrounded phases for calves developed at different rates of gain have not been elucidated. Additionally, it is important to evaluate these potential interactions within the context of an entire production system as opposed to evaluating each phase independently because of the potential for compensatory effects in the subsequent production phase. Therefore, the objective of this research was to evaluate the effects of winter rate of gain and implant use during the winter and summer backgrounding phases on animal performance and carcass characteristics.

Procedure

A backgrounding systems study was conducted at the University of Nebraska-Lincoln Eastern Nebraska Research Extension and Education Center (ENREEC) near Mead, Nebraska. For two consecutive years, 240 weaned crossbred steer calves (Initial BW = 553 lb; SD = 0.36 lb) were used in a 2 x 3 factorial arrangement with factors consisting of two rates of gain (LOW targeted at 1 lb/d or HIGH targeted at 2 lb/d) and three implant strategies: NONE, SINGLE(Revalor-G [40mg trenbolone acetate and 8mg estradiol] during summer grazing), and MULTIPLE (Ralgro [36 mg zeranol] during both winter backgrounding and Revalor-G during summer grazing). Upon arrival, steers were weighed, individually identified, and backgrounded for a 30-day period before starting the experiment. Steers were limit fed for five days prior to trial initiation at 2% of BW with a diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE). Steers were weighed for two consecutive days to account for gut fill variation on 0 d and 1 d of winter phase. Calves were stratified by BW and assigned at random to a treatment on day 1 with 10 head/pen and 4 pens/treatment each year. Calves remained within treatment groups throughout all production phases.

Winter backgrounding

Calves were winter backgrounded in a dry lot system for 148 days with a diet consisting of smooth bromegrass hay, modified distillers grains (MDGS), and supplement. Steers targeted at a HIGH rate of gain consumed a diet of 66% smooth bromegrass hay, 30% MDGS, 3.5% supplement which provided vitamins, minerals, and 200 mg/hd monensin daily. Urea was included at 0.50% of diet DM to ensure RDP was not limiting, and the diet was 13.3% CP. Steers targeted at a low rate of gain were fed a diet consisting of 86% smooth bromegrass hay, 10% MDGS, 3% supplement to provide vitamins, minerals, and 200 mg/hd monensin daily. Urea was included at 1% of diet DM and the dietary CP was 11.4%. All steers were fed ad libitum with diets fed twice daily to ensure all the feed would fit in the

Table 1. Effects of winter rate of gain and implant strategy on winter backgrounding performance

	Treatments[1]									
Winter ROG	LOW Gain			HIGH Gain			SED	*P*-value[2]		
Implant Strategy	NONE	SINGLE	MULTI	NONE	SINGLE	MULTI		Winter ROG	Implant	Winter ROG* Implant
DOF[3]	148	148	148	148	148	148				
Initial BW, lb	552	552	553	553	552	552	1	1.00	0.47	0.35
Ending BW, lb	728[d]	741[c]	751[c]	840[b]	841[b]	878[a]	10	<0.01	<0.01	0.15
ADG, lb	1.19[d]	1.28[c]	1.34[c]	1.94[b]	1.95[b]	2.20[a]	0.07	<0.01	<0.01	0.16
DMI, lb	18.0	17.5	18.3	19.5	19.5	20.5	0.49	<0.01	0.11	0.76
F:G[4]	15.12[d]	13.58[c]	13.67[c]	10.05[b]	10.03[b]	9.15[a]		<0.01	<0.01	0.15

[1]Low Gain targeted 1 lb ADG during the winter phase by feeding smooth bromegrass hay with 10% modified distillers grains. High Gain targeted 2 lb ADG during the winter phase by feeding smooth bromegrass hay with 30% modified distillers grains. NONE = No implant during winter and summer phases. SINGLE = No implant during winter phase and Revalor-G during summer phase (40mg TBA and 8mg estradiol). MULTI (MULTIPLE) = Ralgro during winter phase and Revalor-G during summer phase.

[2]*P*-value: Winter ADG = effect of supplementing LOW gain versus HIGH gain over 2 years during the winter phase. Implant = effect of implant strategy during the winter and summer phases. Winter ADG * Implant = Interaction of Winter ADG and implant strategy during winter and summer phases. Significance declared at $P < 0.10$.

[3]Days on feed

[4]Analyzed as G:F.

[abcd]Different superscripts differ ($P < 0.10$) when the supplement by implant interaction is significant ($P < 0.10$).

Table 2. Effects of winter rate of gain and implant strategy on summer grazing performance

	Treatments[1]									
Winter ROG	LOW Gain			HIGH Gain			SED	*P*-value[2]		
Implant Strategy	NONE	SINGLE	MULTI	NONE	SINGLE	MULTI		Winter ADG	Implant	Winter ADG* Implant
DOF[3]	56	56	56	56	56	56				
Initial BW, lb	738[d]	751[c]	760[c]	850[b]	850[b]	888[a]	10	<0.01	<0.01	0.15
Ending BW, lb	816[d]	842[c]	845[c]	904[b]	918[b]	962[a]	13	<0.01	<0.01	0.10
ADG[4], lb	1.42	1.62	1.53	0.98	1.23	1.30	0.09	<0.01	0.02	0.48
Compensation[5], %	21	23	9	-	-	-				

[1]LOW gain targeted 1 lb ADG during the winter phase by feeding smooth bromegrass hay with 10% modified distillers grains. HIGH gain targeted 2 lb ADG during the winter phase by feeding smooth bromegrass hay with 30% modified distillers grains. NONE = No implant during winter and summer phases. SINGLE (SINGLE) = No implant during winter phase and Revalor-G during summer phase (40mg TBA and 8mg estradiol). MULTI (MULTIPLE) = Ralgro (36 mg zeranol) during winter phase and Revalor-G during summer phase.

[2]*P*-value: Winter ADG = effect of supplementing LOW gain versus HIGH gain over 2 years during the winter phase. Implant = effect of implant strategy during the winter and summer phases. Winter ADG * Implant = Interaction of Winter ADG and implant strategy during winter and summer phases. Significance declared at $P < 0.10$.

[3]Days on feed

[4]SINGLE and MULTI implant strategies are greater than NONE within the same rate of gain.

[5]Calculated as difference in BW at the end of the winter phase minus difference in BW at the end of the summer phase divided by the difference in BW at the end of the winter phase for HIGH gain and LOW gain treatments within implant treatment.

[abcd]Different superscripts differ ($P < 0.10$) when the supplement by implant interaction is significant ($P < 0.10$).

bunk. Cattle within pens assigned to the NONE and SINGLE implant strategies did not receive an implant during the winter backgrounding phase; cattle within pens assigned to MULTIPLE implant strategy received a Ralgro on day 1.

Summer Grazing

The summer grazing phase was 56 days. Each pen (10 head) was allotted to 6 acres of smooth bromegrass pasture which was divided into three 2-acre paddocks that were rotationally grazed. Each paddock was grazed three times in year 1 and four times in year 2. Pastures were fertilized with 100 lb per acre of nitrogen in both years. In YR 1, steers were limit fed for 14 days to give pastures adequate time for growth after fertilization due to cool temperatures. In YR 2, the steers were limit fed for six days. In both years, the limit-fed diet consisted of 50% Sweet Bran (Cargill Corn Milling, Blair, NE) and 50% alfalfa hay fed at 2% of BW. The steers were weighed for two consecutive days: on day 0 and day 1 of summer phase. A one pound per day ADG was assumed for all steers during the limit feeding period to calculate EBW for the winter phase. Cattle assigned to the NONE implant strategy did not receive any implants during the summer backgrounding phase. Steers assigned to SINGLE and MULTIPLE implant strategies were implanted with Revalor-G (Merck Animal Health) on day 1 of the summer phase.

Finishing

Steers entered the feedlot and were limit-fed for five days at 2% of BW with a diet of 50% alfalfa hay and 50% Sweet Bran.

Table 3. Effects of winter rate of gain and implant strategy on finishing performance

	Treatments[1]									
	LOW Gain			HIGH Gain			SED	*P*-value[2]		
Implant Strategy	NONE	SINGLE	MULTI	NONE	SINGLE	MULTI		Winter ADG	Implant	Winter ADG* Implant
DOF[3]	126	129	129	126	119	119				
Initial BW, lb	820[d]	844[c]	848[c]	907[b]	921[b]	965[a]	8	<0.01	<0.01	0.05
Final BW, lb	1395[d]	1440[c]	1450[bc]	1477[b]	1462[bc]	1514[a]	13	<0.01	<0.01	0.06
HCW, lb	879[d]	907[c]	915[bc]	930[b]	921[bc]	954[a]	8	<0.01	<0.01	0.06
ADG, lb	4.55	4.62	4.65	4.49	4.54	4.61	0.05	0.18	0.13	0.93
DMI[4], lb	28.8	29.1	29.7	28.3	29.4	30.2	0.4	0.80	<0.01	0.33
F:G	6.33	6.30	6.39	6.30	6.48	6.55	0.002	0.15	0.16	0.42
REA, in	13.7	13.7	14.0	14.0	13.8	14.6	0.2	0.04	<0.01	0.35
Fat, in	0.60[b]	0.65[ab]	0.64[ab]	0.66[a]	0.60[b]	0.61[ab]	0.02	0.80	0.97	0.07
Marbling	514	505	516	560	520	506	17	0.22	0.23	0.30

[1]LOW gain targeted 1 lb ADG during the winter phase by feeding smooth bromegrass hay with 10% modified distillers grains. HIGH gain targeted 2 lb ADG during the winter phase by feeding smooth bromegrass hay with 30% modified distillers grains. NONE = No implant during winter and summer phases. SINGLE = No implant during winter phase and Revalor-G during summer phase (40mg TBA and 8mg estradiol). MULTI (MULTIPLE) = Ralgro (36 mg zeranol) during winter phase and Revalor-G during summer phase.

[2]*P*-value: Winter ADG = effect of supplementing LOW gain versus HIGH gain over 2 years during the winter phase. Implant = effect of implant strategy during the winter and summer phases. Winter ADG * Implant = Interaction of Winter ADG and implant strategy during winter and summer phases. Significance declared at $P < 0.10$.

[3]Days on feed

[4]Within each rate of gain, NONE and SINGLE cattle had a lower DMI than MULTI with NONE having the lowest.

[abcd]Different superscripts differ ($P < 0.10$) when the supplement by implant interaction is significant ($P < 0.10$).

Steers were consecutively weighed for two days on 0 d and 1 d of the finishing phase. A one pound per day ADG was assumed for all steers during the limit feeding period to calculate EBW for the summer phase. In the finishing phase, all steers were given the same implant strategy of 40 mg of estradiol and 200 mg of TBA (Revalor-XS; Merck Animal Health, De Soto, KS). Steers were stepped up over a 21-d period using 4 step-up diets in which corn stalks were reduced from 16% to 5% of diet DM, Sweet Bran was reduced from 50% to 40% of diet DM, and high-moisture corn increased from 30 to 51% of diet DM. The final finishing diet consisted of 51% high-moisture corn, 40% Sweet Bran, 5% corn stalks, and 4% supplement which provided vitamins, minerals, monensin and tylosin. Steers were fed ad libitum once daily. Cattle were fed during the finishing phase for 119, 126, or 129 days. Shipping dates were determined by estimating backfat thickness at 0.60 inch. Backfat measurements were collected via ultrasound between the 12th and 13th rib on day 1, 57, and 89. Steers were harvested at a commercial abattoir where hot carcass weight (HCW) was recorded on the day of harvest and marbling score, longissimus muscle area, 12th rib fat thickness, and yield grade were measured after a 48-hour chill. Final BW was calculated by dividing HCW by a common dressing percentage of 63%.

Statistics

Data were analyzed using MIXED procedure of SAS as a 2 x 3 factorial design with main effects of winter rate of gain (HIGH or LOW) and implant strategy (NONE, SINGLE (Revalor—G only), and MULTIPLE (Ralgro + Revalor G). The model consisted of the main effects and interaction of winter rate of gain and implant strategy. Year was treated as a random effect. The variance estimate was provided as the standard error of the difference (SED) for the simple effects of treatment because random terms are known to inflate estimates of the standard error of the mean. Significance was declared at a $P < 0.10$.

Results

There were no two-way interactions observed during the winter backgrounding phase ($P > 0.15$). The HIGH ADG steers without implants (NONE and SINGLE) gained 1.95 lb/d, which was close to the targeted 2.0 lb/d. The LOW ADG steers without an implant (NONE and SINGLE) gained 1.24 lb/d, which was slightly greater than the target of 1.0 lb/d. As expected, steers receiving the HIGH ADG diet had a greater ADG, EBW, dry matter intake (DMI), and feed conversion (F:G) over steers fed LOW ADG diet. Overall, the use of Ralgro increased ADG of steers by 11.4% during the winter phase. Additionally, Ralgro improved feed conversion and resulted in an additional 26 lb of BW at the end of the winter backgrounding phase compared to steers not implanted.

When cattle were turned out for summer grazing, the steers fed at a HIGH ADG had greater initial BW and maintained heavier EBW than steers fed at a LOW rate of gain. However, the LOW ADG steers had a greater ADG during the grazing period due to compensatory gain. Steers backgrounded at a LOW winter ADG and did not receive a Ralgro (NONE and SINGLE treatments) compensated by 21 to 23% during the summer grazing phase compared to steers wintered at a HIGH ADG with the same implant strategies. Steers wintered at a LOW ADG and received a Ralgro during the winter phase (MULTIPLE) compensated only 9% during the summer grazing phase when compared to

steers in the MULTIPLE HIGH treatment. However, steers that were implanted with a Ralgro during the winter backgrounding phase (MULTIPLE) had greater initial BW when entering the summer grazing phase and maintained BW resulting in greater EBW at the end of the summer grazing phase than cattle not implanted (NONE and SINGLE) within the same level of gain (LOW or HIGH). The use of Revalor-G improved ADG by 17% during the summer backgrounding phase, regardless of winter rate of gain.

Within the finishing phase, cattle fed a HIGH rate of gain during winter backgrounding had greater initial BW, final BW, and HCW. Steers fed HIGH ADG during winter backgrounding and administered an implant at both growing phases (MULTIPLE) resulted in the greatest HCW with no differences in finishing ADG or F:G. Both implant strategy and winter rate of gain had a large impact on HCW. For steers backgrounded at a LOW ADG, both the SINGLE and MULTIPLE implant strategies had improved HCW when compared to the NONE but did not differ from one another. This suggests that the HCW response observed at a LOW rate of gain (28 lb) was due to the Revalor-G. For steers backgrounded at HIGH rate of gain, only the MULTIPLE implant strategy improved HCW, suggesting that the additional 32 lb of HCW is attributed to the Ralgro. These observations suggest that steers respond significantly to a SINGLE implant strategy at a LOW rate of gain and respond to a MULTIPLE implant strategy at both LOW and HIGH rates of gain. This study suggests that cattle in a 3 phase yearling system gaining 1.19 lb (LOW) ADG during the winter phase would benefit from either implant strategy (SINGLE or MULTIPLE) and cattle targeted to gain 1.94 lb ADG (HIGH) during the winter phase would benefit from an implant at each phase (MULTIPLE). The combination of a winter backgrounding program, targeting a HIGH rate of gain, and a MULTIPLE implant strategy during the backgrounding phases increased HCW by 75 lb. Overall, the data from this study align with previous conclusions that implants improve performance within each phase of production and higher rates of gain during the winter backgrounding phase result in greater ending body weight and HCW.

Conclusion

Implant strategy and rate of gain during the winter backgrounding phase had additive effects increasing animal performance throughout all phases. Furthermore, combining a MULTIPLE implant strategy and HIGH rate of gain during winter backgrounding resulted in 75 lb of additional HCW.

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Effects of Strategic Supplementation on Return to Management and Performance of Yearling Cattle

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Summary with Implications

A three-year experiment evaluated the effects of two supplementation strategies on yearling cattle performance and producer returns to management. Yearling cattle grazed on crested wheatgrass pastures and were supplemented either throughout the entire grazing season, only during the latter part of the grazing season, or not supplemented at all. The supplemented yearlings received 3.5 lb of dried distillers grains with solubles 6 days/week. On average non-supplemented yearlings had an average daily gain of 1.51 lb/d and providing supplement increased average daily gain by 0.5 lb/d. Yearlings supplemented during the latter part of the season had similar performance to yearlings supplemented the entire season, with decreased supplementation costs. Providing supplement through the entire grazing season returned $14.96/animal and providing supplement during the latter part of the grazing season returned $32.21/animal more than the non-supplemented group. Strategic supplementation as grass quality declines is a management tool to increase gain of yearlings and financial return to management.

Introduction

Cool season grasses, such as crested wheatgrass decline in crude protein throughout the grazing season (*2023 Nebraska Beef Cattle Report*, pp. 29–31). As available forage quality decreases, animal gains can also decrease. Previous research has suggested that supplementing yearlings on pasture with high protein feeds, such as dry distillers grains with solubles (DDGS) can increase yearling performance compared to not providing supplement. Strategically supplementing with a high protein feed source, as forage quality decreases, could provide opportunities for producers to increase performance and profitability of yearlings grazing cool season grasses in the summer. With strategic supplementation, a producer would feed less overall, and therefore save money on feed and labor costs compared to providing supplementation over the whole season. Thus, strategic supplementation could be used as a cost-effective way to increase animal performance and return to management. The purpose of this experiment was to evaluate the effect of DDGS supplementation during the whole summer grazing season or the second half of the grazing season on performance and return to management of yearlings grazing crested wheatgrass pastures against no supplement control.

Table 1. Description of animal type, and supplementation strategies across three experimental years[1] for yearlings[2] grazing crested wheatgrass pastures.

	Year 1	Year 2	Year 3
Yearling Description			
Initial Wt[3]	733 ± 34	582 ± 42	774 ± 96
Sex	Steers	Heifers	Steers
Days of Supplementation per Treatment[4]			
CONT	0	0	0
FULL	125	99	111
HALF	70	55	56
Pounds of Supplement Fed per Treatment			
CONT	0	0	0
FULL	375	297	333
HALF	210	165	168

[1] Experimental years were 2019 (year 1), 2020 (year 2), and 2021 (year 3)

[2] All yearlings were received from a single source cooperator under their management strategy, which included vaccinations and implants prior to their arrival at High Plains Agriculture Laboratory.

[3] Initial weights are recorded as a raw mean with standard deviations.

[4] Treatments across all experimental years were CONT (no supplement was fed), FULL (3 lb of supplement was fed everyday through the grazing period), STRAT (3 lb of supplement was fed everyday beginning at the assumed midway point through the grazing period).

Procedure

A three-year (2019–2021) grazing experiment was conducted at the High Plains Agriculture Laboratory, near Sidney, Nebraska. This experiment investigated the effects of changing forage quality and strategic supplementation of DDGS on yearling performance and return to management among a variety of economic conditions. Three treatments were developed to evaluate two supplementation strategies against no supplementation. The control treatment (CONT) received no supplement, the full treatment (FULL) received 3.5 lbs (dry matter) of DDGS 6 days a week throughout the grazing period, and the strategic treatment (STRAT) received 3.5 lbs (dry matter) of DDGS 6 days a week only during the latter part of the grazing period. The FULL treatment received supplement for an average of 112 days, while the STRAT treatment received supplement for an average of 60 days, which was 54% of the grazing period. The supplement was fed in bunks placed directly in their pastures. Yearlings were stocked at approximately 10.5 acres per head on pastures containing primarily crested wheatgrass. Twelve total pastures were used in years 1 and 2 (n=4 per treatment), while nine pastures were used

Table 2. Average yearling performance across experimental years for each treatment.

	CONT	FULL	STRAT	SEM	*P*-value
Initial Wt, lb	701	695	699	17.6	0.98
Final Wt, lb	873[b]	924[a]	916[a]	14.8	0.05
ADG, lb/d	1.51[b]	2.04[a]	1.95[a]	0.066	< 0.01

[a, b] Means within a row with different superscripts differ ($P < 0.05$)

Table 3. Average yearling performance across treatments for each experimental year.

	Year 1	Year 2	Year 3	SEM[1]	*P*-value
Initial Wt, lb	750[a]	579[b]	766[a]	19.2	< 0.01
Final Wt, lb	1021[a]	750[c]	941[b]	16.2	< 0.01
ADG, lb/d	2.19[a]	1.74[b]	1.60[b]	0.072	< 0.01

[1] SEM, standard error of the mean is reported as the largest value of the three years.

[a, b, c] Means within a row with different superscripts differ ($P < 0.05$)

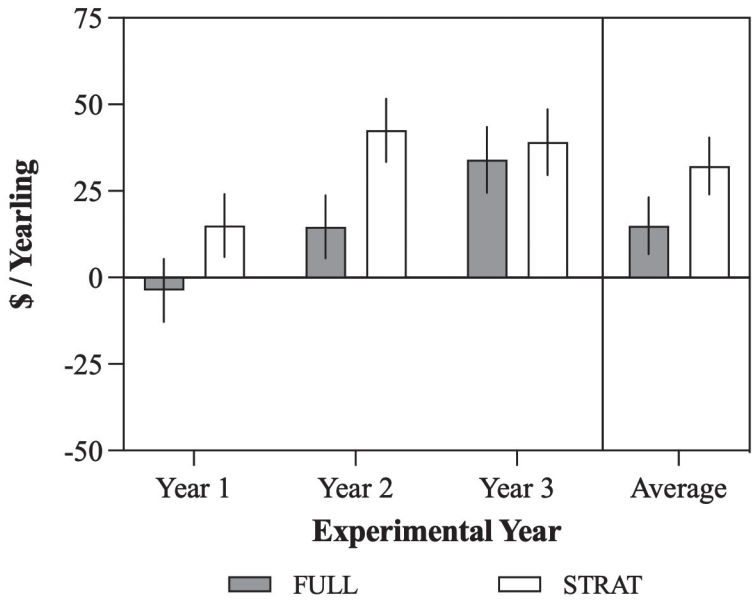

Figure 1. Experimental year differences in return to management for treatments across ten years of average economics (cattle and DDGS prices). Return to management for FULL and STRAT is subtracted from average return to management for CONT to display differences in choosing to supplement or not.

in year 3 (n=3 per treatment). Pasture was the experimental unit. Initial body weights, yearling sex and grazing length varied throughout the experiment due to calf and grass availability (Table 1). On average, yearlings grazed for 112 days from late May through early September. To determine initial and final body weights and average daily gain (ADG), the yearlings were weighed in the morning for two consecutive days at the onset and the end of the trial.

Economic Analysis

To simulate return to management in the treatments among a variety of marketing conditions, a partial budgeting approach was taken using economic data from the previous decade. Average live cattle prices and DDGS prices for Nebraska were obtained from 2012 through 2021. Recorded cattle performance was applied to the market prices. Although the experiment was only conducted for three years (2019, 2020, and 2021), variation of the cattle market is independent of the observed cattle performance. The potential change in yearling value was calculated using the three years of cattle weight information and applying it to the ten years of collected cattle market information. Yearling values were calculated based on the average weight from each treatment group and the corresponding price per cwt. The cost of supplementation in each treatment was calculated by multiplying the price of DDGS in each economic year by the amount of supplement fed to a yearling in the FULL and STRAT treatments during each experimental year. To determine the return to management in each treatment scenario, the cost of supplement for each year was subtracted from the change in yearling value. Then the change in cattle value for the CONT treatment was subtracted from the change in yearling value for FULL and STRAT to evaluate the return to management of supplementation (i.e. the return to the labor of providing the supplement). Additionally, value of gain was calculated by dividing the difference in initial and final value by the increase in weight.

Applying the three years of biological data to the ten years of economic data, allows for evaluation of potential differences for each treatment among a variety of market conditions. It is widely accepted that cattle markets typically follow a ten-year cycle of variation. By simulating potential marketing scenarios in this manner, the inherent variability of market prices for both DDGS and live cattle is accounted for.

Results

There were no significant interactions ($P > 0.53$) between experimental year and treatment. There was an effect ($P < 0.01$) of treatment (Table 2) and year (Table 3) on ADG. Across all years, supplementation increased ($P < 0.01$) gains by 0.5 lb/d and final body weight over the control but strategy did not differ ($P \geq 0.31$) in ADG or final body weight. This suggests that delaying supplementation to latter half of the grazing period will result in as much improvement in performance as supplementing all season and require less total supplement and labor.

Across 10 economic years, the average DDGS price was $161.99/ton. Utilizing 10 years of economic data, within the three experimental years, return to management was $14.96/yearling more for FULL and $32.21/yearling more for STRAT than CONT yearlings (Figure 1). These results suggest that on average supplementation will increase return and that the STRAT will increase return to management more than the FULL treatment. However, within year, a significant increase ($P < 0.01$) in return to management over the CONT was

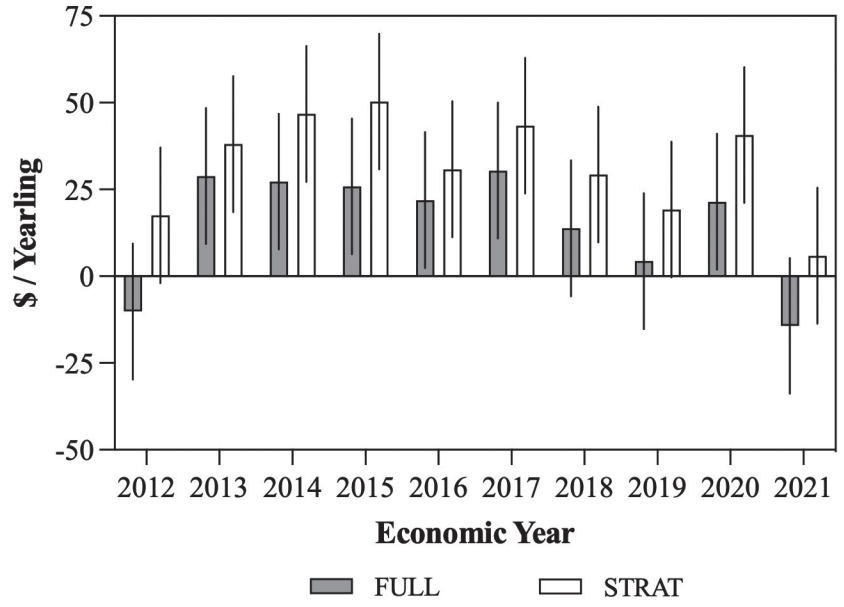

Figure 2. Economic year (2012–2021) differences in return to management for treatments. Return to management for FULL and STRAT is subtracted from average return to management for CONT to display differences in choosing to supplement or not.

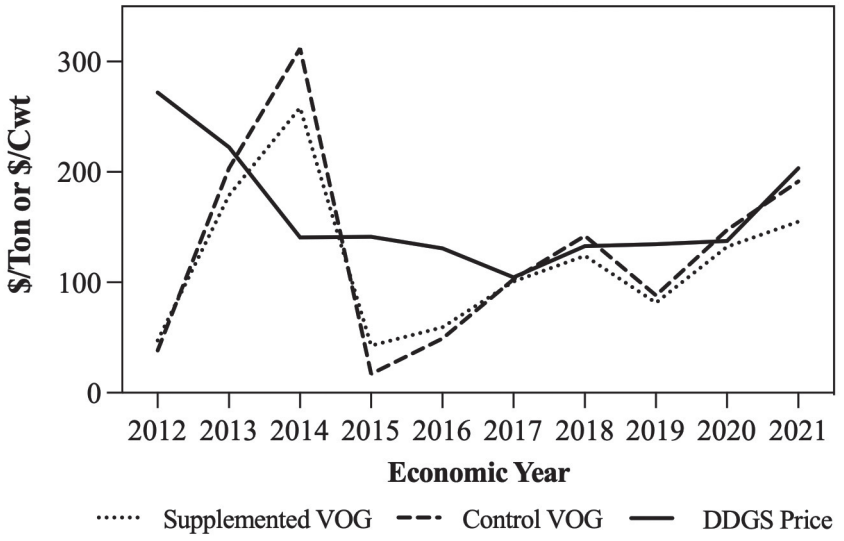

Figure 3. Economic year (2012–2021) prices of DDGS ($/ton) compared to calculated value of gain (VOG, $/cwt). Supplemented VOG displays the average between the full and strategic treatments.

observed only in experimental year 3 for FULL and experimental year 2 and 3 for STRAT. There did not appear to be an advantage to supplementation in year 1 due to the high rate of gain in that year, resulting in the supplemented cattle being over 1,000 lbs when they were sold.

The return to management for the supplemented treatments across three experimental years within each economic year (2012–2021) are shown in Figure 2. There were no economic year by treatment interactions (P = 0.99), meaning the treatments displayed the same trend in each year. When averaging the return between the FULL and STRAT treatments, there was an economic year effect (P < 0.01) and a supplementation effect (P < 0.01). In 7 of the 10 years evaluated, supplementing would have increased return, regardless of the strategy used. In 2012, the price of DDGS were too high in combination with an overall low value of gain (Figure 3). In 2019, there was an overall lower value of gain relative to the price of DDGS. In 2021, there were increased prices of DDGS combined with a higher value of gain for not supplementing (CONT). These scenarios resulted in a reduction in return for those supplementation strategies observed in Figure 2. Looking at 2015 and 2016, there was a relatively low value of gain compared to higher prices in DDGS. However, the value of gain for not supplementing (CONT) was lower than the value of gain for supplementing (Figure 3), resulting in greater return for those strategies (Figure 2).

Conclusion

Forage quality of cool season pasture declines throughout the summer grazing season which can reduce the rate of gain in yearlings. Providing high protein supplementation to yearlings on cool-season pasture will increase final body weights and ADG compared to not providing supplement. This experiment has demonstrated that strategically supplementing as forage quality declines will provide similar performance to supplementing throughout the entire grazing season while reducing cost. Overall, strategic supplementation as grass quality declines throughout the grazing season is a practical management tool to benefit performance for yearlings and return to management.

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Forage Evaluation of Crested Wheatgrass

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Summary with Implications

An experiment evaluated the forage value of crested wheatgrass (CWG) harvested throughout the grazing season near Sidney, Nebraska over a two-year period (2019–2020). The purpose of the evaluation was to determine forage quality and rumen undegradable protein (RUP) content to help producers with supplementation decisions for cattle grazing monoculture CWG pastures. In vitro dry matter disappearance quadratically decreased from 54% in May to 37% in September of 2019, with no changes throughout 2020, averaging 43%. In both years, crude protein (CP) decreased throughout the growing season while rumen undegradable protein (RUP) increased (as % CP). Digestible RUP was less than 0.50% of DM for all samples collected. Producers with cattle grazing CWG monoculture pastures could use these data to assist with supplementation decisions.

Introduction

Monoculture pastures of crested wheatgrass (CWG) are commonly grazed by cattle in the panhandle of Nebraska. In the vegetative stage, CWG peaks in CP content, which then decreases as it matures throughout the growing season. Mature CWG plants are low in protein, which may limit forage digestion and body weight gain in stockers; therefore, supplementation may be beneficial for part of the grazing season. Performance improvements have been observed for growing steers supplemented with 2 different protein sources while grazing CWG (*2017 Nebraska Beef Cattle Report*, pp. 36–37).

Although additional protein supplementation may improve the performance of growing cattle, there are limited data available on protein composition of CWG. Crude protein is a combination of rumen degradable protein (RDP) and rumen undegradable protein (RUP). Rumen degradable protein is utilized by microbes in the rumen and not directly available to the animal. The RUP fraction is not degraded by microbes in the rumen and is partially degraded by the animal in the gastrointestinal tract. As forages mature, the ratio of RDP:RUP and digestibility of protein change; therefore, CP alone does not accurately represent the amount of protein actually available to the animal throughout the grazing season. Metabolizable protein (MP) is the true protein digested in the small intestine and absorbed as amino acids and is calculated as Microbial CP + digestible RUP. The objective of this study was to evaluate the protein composition of CWG as it matured. Knowing the amount of RUP available to cattle grazing CWG can help producers calculate MP supply and aid supplementation decisions throughout the grazing period.

Procedure

Sample Collection

Two large pastures, comprised of 95% CWG, were divided into 13 paddocks (85 acres, 3 paddocks and 105 acres, 10 paddocks). Within each pasture, two paddocks were assigned at random for sampling (Pasture 1 = paddocks 2 + 4; Pasture 2 = paddocks 8 + 10). Forage samples were collected twice each month from two random locations within the assigned paddocks by hand clipping forage within a 0.25 m^2 quadrat at ground level. Plant species other than CWG were removed from the sample. For each year, samples were composited by pasture and month. Samples from 2019 (n = 10) were harvested in May, June, July, August, and September while 2020 samples (n = 8) were harvested in May, June, July, and August due to drought conditions. Local precipitation from May 1st to September 30th was 21.8 inches for 2019 and 5.9 inches for 2020 with a 10-yr average precipitation of 13.8 inches. Yearlings were stocked continuously throughout the grazing period at a density of 10.3 acres per steer on all paddocks.

Lab Analysis

Two steers with ruminal and duodenal cannulas were utilized to collect rumen fluid for the *in vitro* and *in situ* lab assays. Steers were fed a diet consisting of 70% smooth bromegrass hay, 23% dried distillers grains plus solubles, 6% dry rolled corn, and 1% supplement (twice daily).

A modified method was used for *in vitro* dry matter disappearance (IVDMD) with the inclusion of 1 g/L of urea to the McDougall's buffer to reduce variation among donor animals and their diets. An *in-situ* procedure was used to determine protein digestibility. Freeze dried CWG samples (2 mm particle size) were composited by month and pasture with 10 composite samples for year 1 and 8 samples for year 2. Samples were incubated in the rumen using Ankom R510 Dacron bags (1.25 g of sample/bag:16 bags/sample). All 18 samples were incubated in each steer with 8 replicates/sample/steer (144 bags/steer). Within each steer, 4 bags from each sample were incubated in the rumen for 20 hours and the remainder for 30 hours (20 hour, 72 bags/steer; 30 hour, 72 bags/steer). Post rumen incubation, half of the samples from each incubation time were assigned to duodenal incubation (20 hour, 36 bags/steer; 30 hour, 36 bags/steer). One bag from each rumen incubation time (and one from each steer) was assigned to each steer for a total of 4 bags/steer for each sample. Duodenal bags were incubated in a pepsin HCL solution (1g pepsin/L and 0.01 N HCl) maintained at 37˚C for 3 hours to simulate abomasum digestion before insertion.

Table 1. Crested wheatgrass through the 2019 grazing season at Sidney, NE

							Orthogonal Contrasts[7]		
Item	May	June	July	August	September	SEM	Linear	Quadratic	Cubic
CP, % DM[1]	9.5	7.7	6.6	6.2	6.3	0.10	<0.01	<0.01	0.35
RUP, % CP[2]	8.8	12.0	13.9	16.2	17.7	1.00	<0.01	<0.01	0.87
RUP, % DM[3]	0.80	0.90	0.93	0.98	1.09	0.06	<0.01	0.33	0.23
RUP dig., %[4]	39.9	43.3	42.3	45.3	46.6	5.72	0.02	0.45	0.21
Dig RUP, % DM[5]	0.40	0.43	0.42	0.45	0.49	0.03	0.02	0.94	0.45
IVDMD, % DM[6]	54.0	52.1	45.6	41.9	37.0	0.01	<0.01	0.02	0.35

[1] CP, % DM—Crude protein as a percent of total dry matter

[2] RUP, %CP—rumen undegradable protein as a percent of crude protein

[3] RUP, % DM—rumen undegradable protein as a percent of total dry matter

[4] RUP dig, %—rumen undegradable protein digestibility

[5] Dig RUP, % DM—digestible rumen undegradable protein as a percent of total dry matter (RUP as % of DM that is digested by cattle)

[6] IVDMD, % DM—In vitro dry matter disappearance as a percent of total dry matter

[7] Orthogonal Contrasts—*P*-values describing changes over time

Table 2. Crested wheatgrass through the 2020 grazing season at Sidney, Ne

						Orthogonal Contrasts[7]		
Item	May	June	July	August	SEM	Linear	Quadratic	Cubic
CP, % DM[1]	12.1	9.6	6.8	5.3	0.10	<0.01	0.02	0.05
RUP, % CP[2]	8.7	11.9	17.8	20.7	0.90	<0.01	0.92	0.19
RUP, % DM[3]	1.03	1.14	1.21	1.06	0.06	0.58	0.06	0.50
RUP dig, % CP[4]	35.4	36.1	38.0	39.8	5.42	0.25	0.85	0.90
Dig RUP, % DM[5]	0.37	0.36	0.38	0.40	0.04	0.49	0.73	0.86
IVDMD, % DM[6]	41.8	46.2	41.7	42.8	0.02	0.91	0.54	0.26

[1] CP, % DM—Crude protein as a percent of total dry matter

[2] RUP, %CP—rumen undegradable protein as a percent of crude protein

[3] RUP, % DM—rumen undegradable protein as a percent of total dry matter

[4] RUP dig, %—rumen undegradable protein digestibility

[5] Dig RUP, % DM—digestible rumen undegradable protein as a percent of total dry matter (RUP as % of DM that is digested by cattle)

[6] IVDMD, % DM—In vitro dry matter disappearance as a percent of total dry matter

[7] Orthogonal Contrasts—*P*-values describing changes over time

Bags were then placed in the duodenal cannula one at a time every 5 minutes, with a maximum of 18 samples per animal daily. Bags were recovered in the feces within 24 hours after duodenal insertion and placed in a freezer. At the end of the collection period, bags were thawed, rinsed, refluxed for 1 hour in neutral detergent solution, dried in a 60˚C forced air oven for 24 hours, and weighed to measure RUP digestibility. Samples that were only rumen incubated were also refluxed in neutral detergent solution to remove any microbial attachment and used to measure RUP content: RUP, % DM = [(Residue N * Residue weight) * 6.25]/original sample DM. All incubated samples were analyzed by Ward Laboratories for nitrogen content to calculate RUP (N remaining in bags after rumen incubation) and total tract indigestible protein (TTIDP; N remaining in bags recovered from feces).

Statistical Analysis

The mixed procedure of SAS 9.4 was used to analyze all data. Individual observations calculated from 4 bags (2 after rumen incubation and 2 after duodenal incubation) for each composite sample were considered an experimental unit. Orthogonal contrasts were used to analyze changes in forage quality over time. Due to very different precipitation amounts in the 2 years, data were analyzed by year with month and pasture as fixed effects for IVDMD and CP data. Steer was included as a random effect for RUP and RUP digestibility data with pasture, month, and rumen incubation time as fixed effects. A *P*-value of less than 0.05 was considered significant.

Results

There were no significant interactions between month and incubation time ($P \geq 0.28$) and no significant biological effects of 20-hour and 30-hour incubation times ($P \geq 0.07$). Therefore, main effects of month are shown in Tables 1 and 2 for 2019 and 2020, respectively. Forage quality quadratically decreased throughout the growing season in 2019 (IVDMD, $P = 0.02$) but stayed relatively stable in 2020 ($P \geq 0.26$). This was primarily due to low IVDMD early in 2020 which likely resulted from minimal new growth during the drought and dead

mature plant matter from the previous year being included in the sample. In both years, CP decreased throughout the grazing season ($P \leq 0.02$) while RUP as a percent of CP increased ($P < 0.01$). In 2019, RUP (% DM) and RUP digestibility increased linearly throughout the growing season ($P \leq 0.02$) resulting in greater digestible RUP (% DM) later in the growing season. In 2020, RUP (% DM), RUP digestibility, and digestible RUP (% DM) did not significantly change throughout the grazing season ($P \geq 0.06$). These data suggest that CWG may increase in digestible RUP throughout the growing season in years with above average precipitation while forage quality, including digestible RUP, remains relatively constant throughout the growing season in years with below average precipitation. Research reported in the *2023 Nebraska Beef Cattle Report* (pp. 26–28) suggests a positive economic impact from supplementing additional RUP to yearlings grazing crested wheatgrass during the grazing season.

Conclusion

In a monoculture CWG pasture being continuously grazed, CP decreased throughout the grazing season as RUP (% CP) increased. Digestible RUP of CWG ranged from 0.36 to 0.49 (% DM) throughout the grazing season for two consecutive years with varying precipitation. Nutritionists that have clients grazing yearlings on CWG monoculture pastures should assume that less than 0.5% of all DM consumed is digestible RUP.

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Evaluation of Ankom F58 Filter Bags Compared to Beakers for Analysis of Neutral Detergent Fiber

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Summary with Implications

Feed ingredient, feed refusals, duodenal and fecal samples were analyzed to compare two methods of determining neutral detergent fiber. All samples were weighed into Ankom F58 fiber bags and analyzed using an Ankom 2000 automated fiber analyzer. Results were then compared to the Van Soest beaker method. The fiber values determined from both methods were within 3.5% of one another, with the beaker method being consistently greater compared to the Ankom method, except for fecal samples. Variability in fiber estimates for ingredients, feed refusals, and feces translated to substantial inconsistency in estimated neutral detergent fiber digestibilities among treatments. It is important to utilize a technique that results in correct neutral detergent fiber values because these values are used to further calculate digestibility of diets.

Introduction

Forages are a crucial ingredient in formulating cattle feed rations. Additionally, forage is the most consumed nutrition source in a beef animal's lifetime, constituting over 80% of the total feedstuffs. Having accurate neutral detergent fiber (NDF) and acid detergent fiber (ADF) is vital in the formulation of rations. Both NDF and ADF values are used to estimate the total amount of digestible nutrients of feedstuffs. Accurate estimates of fiber content are important so rations can be efficiently formulated for animal performance while also costing less for the producer. The Ankom Fiber Analyzer was developed to facilitate ease and minimize human error during the process of determining the NDF and ADF values of the samples. The Ankom machine can be more efficient than the Van Soest beaker method. With the beaker method, a person is limited with both time and equipment when analyzing NDF values, whereas in the Ankom machine, one can place up to 24 individual bags onto the trays and let the machine complete the reflux to determine fiber. Additionally, the process is automated which may lead to less human error and improved precision in comparison to the beaker method. However, the use of the Ankom F57 bags with the Ankom machine created concerns due to washout of small particles, especially with biological samples such as fecal and duodenal samples that are used to estimate diet digestibility. Ankom has a newer bag (Ankom F58) which uses a special polymer that promotes a finer porosity. This increases flow throughout the bag reducing clumping of the sample and washout of small particles. Therefore, the objective of this experiment was to compare the NDF values derived from the Van Soest beaker method and the Ankom machine using Ankom F58 bags.

Procedure

Neutral detergent digestibility was measured by collecting fecal, duodenal, feed refusal, and ingredient samples from a digestion trial with 6 periods and 6 steers (*2021 Nebraska Beef Cattle Report*, pp. 46–49). A total of 36 fecal, duodenal, and feed refusal samples were used in duplicate to acquire an average NDF value. Ingredient samples from each period including steam-flaked corn, dry-rolled corn, high-moisture corn, corn silage, and Sweet Bran, were also run in duplicate to acquire an average NDF value. Ankom F58 sample bags were used rather than F57 sample bags due to the finer porosity (25 microns vs. 6–9 microns for F57 and F58, respectively). The finer porosity is due to a different polymer used in the F58 bags that is said to increase the flow throughout each bag while reducing clumping of the sample.

Sample Preparation

After collection, samples were freeze-dried or dried in a 60°C oven, ground through a 1-mm screen using a Wiley Mill and composited by animal within period. All samples were 1-mm when analyzed for NDF, except high starch samples (corn and orts) which were ground through a 1-mm screen and then ground through the cyclotec (0.5 mm).

Ankom procedure

All samples were weighed into Ankom F58 bags in duplicate. The bags each contained 0.5 gram of sample and then sealed twice with a 6" impulse bag sealer. A total of 24 bags were placed on bag suspenders into the Ankom 2000 automated fiber analyzer. Sodium sulfide and alpha amylase were added according to the Ankom machine NDF instructions:1.0 mg of sodium sulfide and 1 mL of alpha amylase distributed over the top of the bags and 4 mL of alpha amylase added to the amylase dispenser with distilled water up to the fill line. The neutral detergent solution was then opened to allow it to flow into the drum. The machine was turned on and set to the "NDF" preset cycle. After the cycle successfully ran, the samples were rinsed in distilled water to get any residue off the outside surface. Then the samples were placed on a drying rack to dry for 24 hr at 100°C. Samples were then weighed to compare the original weight of the sample to the weight after the NDF procedure to determine the NDF content.

Beaker procedure

Samples were also analyzed in duplicate using the Van Soest beaker method. Beakers were used to hold 0.5 g of each sample, 0.5 g of sodium sulfate, and 100 mL of neutral detergent solution. Alpha amylase was added to the beaker in 0.5 mL increments (1 mL total) after reflux began and ten minutes prior to filtering. The samples

Table 1. Comparison of a beaker method with the Ankom method for analyzing specific samples for neutral detergent fiber (NDF)

Sample	Beaker NDF[1]	Ankom NDF[2]	Average difference[3]	Correlation[4] (r)
Fecal	42.64%	46.12%	-3.55%	0.38
Duodenal	18.75%	15.18%	2.94%	0.94
Feed refusals	15.63%	13.53%	2.04%	0.87
Ingredient	21.01%	18.68%	2.33%	0.99

[1]Beaker NDF-Value based on Van Soest beaker method.

[2]Ankom NDF-Value based on the Ankom automated NDF method using F58 filter bags.

[3]Avg. Difference-Average NDF value difference between Van Soest method and Ankom machine method.

[4] Correlation Coefficient (r)-Linear correlation

Table 2. Comparison of a beaker method with Ankom F-58 filter bags for analyzing diets with steamed flaked corn (SFC) or high moisture corn with dry rolled corn (HMC/DRC) at 0, 20, and 40% Sweet Bran to find the neutral detergent fiber digestibility (NDFD)[1]

	Treatment					
	SFC			HMC/DRC		
	0	20	40	0	20	40
NDFD Beaker[2], %	24.5	49.2	49.9	25.1	49.6	59.8
NDFD Ankom[3], %	16.6	32.6	41.4	23.6	41.4	48.0

[1]NDFD- Neutral Detergent Fiber Digestibility.

[2]Beaker- NDF value based on Van Soest beaker method.

[3]Ankom- NDF value based on Ankom automated NDF method using F58 filter bags.

were refluxed on a hot plate for one hour. After reflux, samples were filtered using a Whatman 541 filter (22 micron pore size) to isolate NDF material. The filters were folded and dried at 100°C for 24 hr and then NDF content was determined.

Results

The automated Ankom method produced similar NDF results compared to the Van Soest beaker method for 3 of the 4 sample types. As shown in Table 1, there was less than a ±3.5% difference between the two methods. The NDF values for the ingredient, feed refusal, and duodenal samples were slightly greater for the beaker method compared to the Ankom machine, but the correlation between the estimates was high (r = 0.87, 0.94, and 0.99 for diet refusals, duodenal samples, and ingredient samples, respectively). The differences in the absolute values between methods may be a function of washout of particles when using the Ankom filter bags (even though the pore size is smaller), or incomplete solubility of non-NDF material in the beakers. Regardless, there appears to be strong agreement between methods for ingredients, diet refusals, and duodenal samples. However, the NDF values for the fecal samples were greater for the Ankom machine. Additionally, NDF values for the fecal samples between the Ankom and beaker method were not well correlated (r = 0.38). It is unclear why the NDF values for the fecal samples were greater for the Ankom machine and why there was little agreement of the fecal samples between the two methods. Perhaps there was greater fecal NDF loss with the beaker method when using a filter paper with a larger pore size. However, this reason is puzzling since the duodenal, feed refusal, and ingredient samples were all highly correlated between the two methods, and the beaker method produced higher values for those sample types. Further research is needed to determine why the two methods produce different NDF results for fecal samples.

The resulting NDF values between the two methods were used to calculate total tract NDF digestibility of each diet (using fecal, ingredient, and feed refusals NDFs), as shown in Table 2. In general, the calculated digestibility of NDF was greater when using the beaker method as opposed to the Ankom machine. While the two methods agreed in the order of NDF digestibility (e.g. the ranking of treatments with the lowest NDF digestibility to greatest NDF digestibility), the relative difference among treatments was inconsistent, ranging from 1.5 percentage units difference to 16.6 percentage units different in NDF digestibility between both methods. These discrepancies are due to inconsistencies in both estimated NDF intake and NDF excretion. While there was strong correlation between the two methods for ingredients and feed refusals, small differences in NDF content can have a large impact on estimated NDF intake. Furthermore, the disagreement in NDF content of the feces results in inconsistent estimates of NDF excretion. Both factors impact the estimates of NDF digestibility.

Conclusion

Most samples that producers or their nutritionists send to a lab for analysis are ingredient or diet samples. These data suggest there is strong agreement in the resulting NDF estimates when using Ankom F58 filter bags and the traditional NDF beaker method developed by Van Soest. However, there is little agreement between the methods for fecal NDF, which is problematic for researchers wanting to estimate diet NDF digestibility of finishing diets. Having accurate digestibility estimates are important because it allows consultants to develop rations that more accurately target a desired rate of gain, improving producers' efficiency and economic return.

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Effect of Species and Maturity on Small Grain Silage Yield and Quality

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Summary with Implications

A study was conducted to determine the effect of species and maturity on yield and nutritive value of winter-hardy small cereal grains used for silage. Three species were evaluated: cereal rye, winter triticale, and winter wheat at four different stages of maturity: boot, pollination, milk, and soft dough. As species matured, yield increased across all stages, but crude protein (CP) and digestible organic matter (DOM) decreased, except at soft dough where there was a slight increase in DOM. Crude protein was greatest at the boot stage at 17.7% and least at soft dough at 9.8%. When comparing species, rye and triticale resulted in greater nutrient yield per acre. If high quality forage is the goal, harvesting at pollination appeared to increase yield without sacrificing a significant amount of nutritive value compared to boot. For maximized yield, harvesting at soft dough is a better option.

Introduction

Cover crops are useful for sequestering nutrients and improving soil structure, but they can also be used as a forage source to help offset costs and generate additional revenue. Cereal rye is the most commonly planted winter hardy cover crop, but other common options include winter wheat and winter triticale. The harvest window for winter-hardy cereal silage is from early May until late June in the Midwest, offering the unique opportunity for a double cropping system with a summer cash crop. Since yields increase, but nutritive value declines as forage matures, the ideal harvest timing will vary for operations based on the quality of silage needed and timing of subsequent planting. It has also been observed that the different winter hardy small cereals differ in the timing at which they reach the various stages of maturity. Thus, species selection may impact yield, nutritive value, and window of harvest. Therefore, the objective of this study is to evaluate the silage yield and nutritive value of winter wheat, cereal rye, and winter triticale at 4 different maturity stages.

Procedure

In this two-year study, twenty 11 x 80-foot plots located on East Campus at the University of Nebraska-Lincoln were drilled in late October with Arapahoe winter wheat, VNS cereal rye, or NT11406 winter triticale in year 1 and Rymin cereal rye, NT1140 triticale, or Arapahoe wheat in year 2. In the spring, plants were observed regularly for maturity progression and harvested at 4 target stages: boot (majority of heads close to showing), pollination (heads are out and pollinating, yellow anthers visible), milk (white milky substance produced when seed is squeezed), and soft dough (white dough-like substance produced when seed is squeezed). All treatments were fertilized with 60 pounds of nitrogen per acre in the form of ammonium nitrate (NH_4-NO_3). Plots were set up as a randomized complete block design with four blocks (location) and the three species randomly assigned within block to a plot. Within each plot, there was a split plot design of the four harvest timings being randomly assigned to one quarter of the plot. Prior to harvest at each stage, biomass samples were cut at a height of 2 inches by hand to calculate yield. A 5 x 40-foot area of forage was cut with a Carter harvester within each plot at each stage and allowed to wilt, targeting 30–35% dry matter. Once cut the dry matter content was measured using a Koster moisture tester; 30 minutes to an hour later another sample was taken and dry matter content was determined to evaluate the rate of drying and determine an estimated target wilting time. For longer wilt times, this procedure was repeated until it was estimated that the target dry matter was achieved. Samples of the wilted material were taken, and buckets (5 gallon) were then packed and ensiled for 45 days in a non-temperature-controlled storage shed before being opened and sampled. The top 6 inches of material were removed and discarded. The remaining ensiled sample was mixed, and a subsample was obtained. Samples were sent to Dairyland Labs to be analyzed for pH using an Orion pH electrode and fermentation end products via high-performance liquid chromatography (HPLC). Samples were then dried at 60°C and analyzed for crude protein (combustion method) and shipped back to the UNL ruminant nutrition lab where in vitro organic matter digestibility (IVOMD) was measured by incubating samples in buffered rumen fluid for 48 hr. Digestible organic matter (DOM), a proxy for TDN, was calculated by multiplying the IVOMD by the organic matter content of the sample.

Dry matter yield (lbs/ac), CP (% of DM), DOM (% of DM), CP and DOM yield (lb/ac), DM content of plants when cut (DM at harvest), DM content of silage post fermentation, pH, and fermentation end products (lactic, butyric, and acetic acid and ammonia) were all analyzed using the mixed procedure of SAS. Effect of timing of harvest, species, and species by harvest interaction were tested as fixed effects. Year was considered random. When interaction was not significant, it was removed from the model.

Results

The dates at which each species reached these maturity stages are shown in Table 1. All species progressed from boot to soft dough over the time period of about a month. From year 1 to year 2, timing of

Table 1. Harvest dates of winter hardy small cereals species based on achieving the target maturity stage.

	Year 1		
	Rye	Wheat	Triticale
Boot	5/18/20	5/23/20	5/18/20
Pollination	6/1/20	ND[1]	5/29/20
Milk	6/9/20	6/8/20	6/9/20
Soft Dough	6/22/20	6/16/20	6/22/20
	Year 2		
Boot	5/5/21	5/13/21	5/11/21
Pollination	5/12/21	5/24/21	5/24/21
Milk	6/11/21	6/7/21	6/8/21
Soft Dough	6/15/21	6/14/21	6/21/21

[1]The pollination stage of wheat was missed; therefore, no date is available.

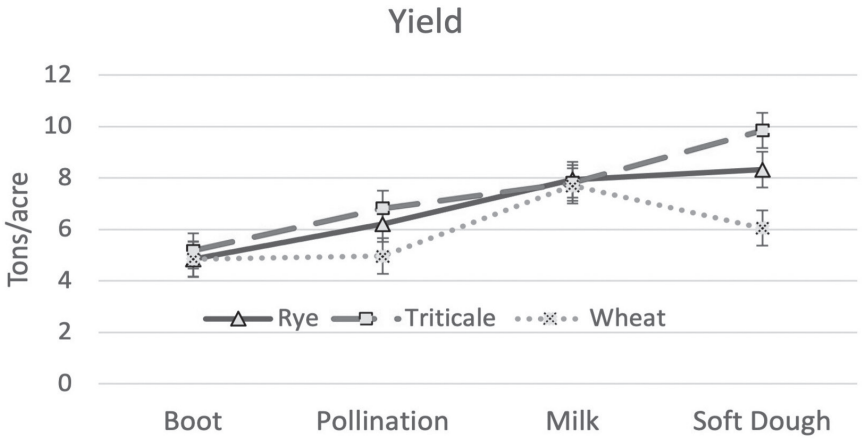

Figure 1. Dry matter yield of wheat, rye, and triticale across 4 stages: boot, pollination, milk, and soft dough. Yield increased for each species across stage except for wheat, which declined at soft dough. Species x Stage $P = 0.03$, Species $P < 0.01$, Stage $P < 0.01$

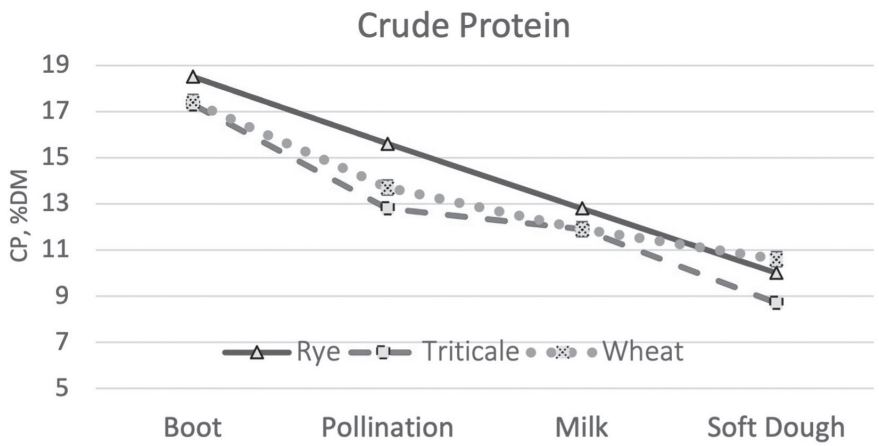

Figure 2. Crude protein as a percent of dry matter of wheat, rye, and triticale across 4 stages. Crude protein declined with maturity across all species. Species x Stage $P < 0.01$, Species $P < 0.01$, Stage $P < 0.01$

harvest for each species varied, likely due to difference in the varieties used. In year 1, rye and triticale were harvested on similar dates and reached boot stage earlier compared to wheat. However, wheat progressed through later stages quickly resulting in wheat reaching milk at the same time as the rye and triticale. The increased rate of maturing for wheat resulting in it reaching soft dough earlier than rye and triticale. In year 2, rye reached boot and pollination earlier than triticale and wheat which had similar timing for these stages. Wheat and triticale also had similar timing at which they reached milk and were about a week earlier than rye. Rye and wheat reached soft dough at the same time and was about a week earlier then triticale. Overall, the window of harvest is slightly shorter for wheat than for rye and triticale.

As the small cereals matured the DM content when cut increased ($P < 0.01$) at 17, 21, 30, and 41% DM for boot, anthesis, milk and soft dough, respectively. Similarly, dry matter yield (Figure 1) increased across all stages, except for wheat, where there was a significant decline at soft dough, likely due to senescence of the lower leaves. Yield of rye and triticale did not differ ($P > 0.05$) except at soft dough where triticale was greater ($P < 0.01$) than rye. Triticale yield was greater ($P < 0.01$) than wheat at pollination and soft dough, with rye being greater ($P \leq 0.05$) than wheat at pollination and soft dough.

Crude protein (Figure 2) decreased ($P < 0.01$) with maturity across all species. Among species, rye was greater ($P \leq 0.01$) than triticale at boot, pollination, and soft dough, but was not different ($P \geq 0.10$) from wheat at boot, milk, and soft dough. At boot, pollination, and milk triticale was not different from wheat ($P \geq 0.07$). Triticale was less than wheat at soft dough ($P < 0.01$).

In terms of DOM (Figure 3), rye and wheat did not differ statistically ($P > 0.05$) but were greater ($P < 0.01$) than triticale. Across species, boot stage had the greatest average DOM concentration at 57.5% and milk had the lowest at 49.3%.

When comparing nutrient yield per acre in terms of energy (DOM) and CP (Figure 4), rye and triticale had greater ($P \leq 0.05$) nutrient yields than wheat with triticale having a slightly greater DM yield with slightly lower energy and protein content

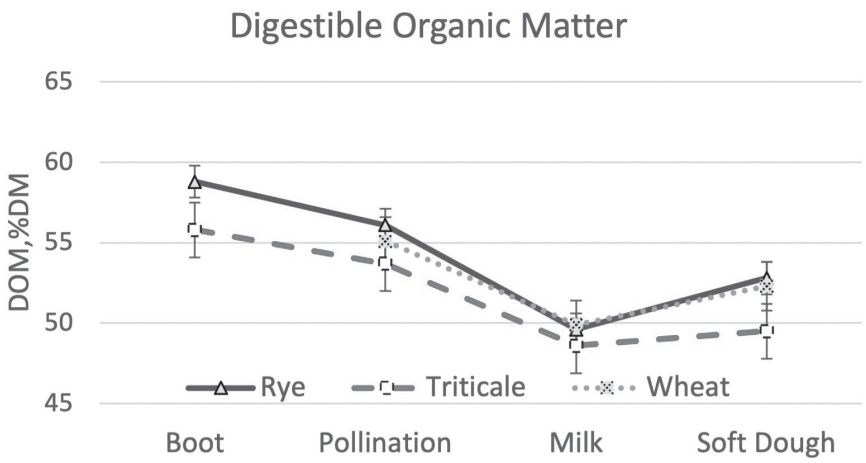

Figure 3. Digestible Organic Matter (DOM), which is a proxy for TDN, as a percent of dry matter for wheat, rye, and triticale across 4 stages. DOM decreased with maturity across species, except at soft dough where there was slight increase, likely due to the formation of the seed head. Species x Stage $P = 0.80$, Species $P < 0.01$, Stage $P < 0.01$.

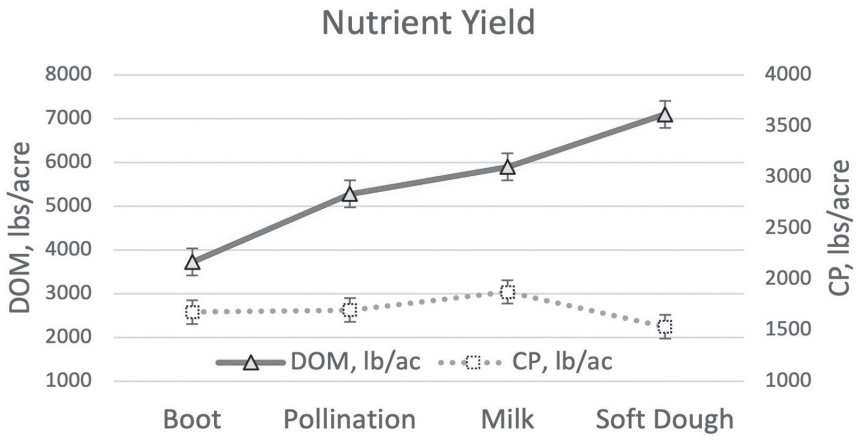

Figure 4. Nutrient yield per acre across 4 stages for all three species: wheat, rye, and triticale. DOM is represented on the left axis and CP on the right axis. Stage DOM $P < 0.01$, Stage CP $P = 0.10$

Table 2. Effect of maturity stage on DM content and the resulting fermentation profile of small cereal grain silage fermented for 45 days.

	Typical Values	Boot	Anthesis	Milk	Soft Dough	SEM	*P*-value
DM, %	-	23d	27c	31b	37a	1.1	<0.01
pH	4.3–4.7	4.3d	4.6b	4.4c	4.6a	0.11	0.01
Lactic Acid, % DM	6.0–10.0	8a	4b	5b	3b	2.6	<0.01
Butyric Acid, % DM	0.5–1.0	0.03	0.35	0.02	0.02	0.18	0.24
Acetic Acid, %DM	1.0–3.0	1.6a	1.6a	1.1b	0.6c	0.67	<0.01
Total Acid, %DM	-	9a	6a	6a	4b	3.2	<0.01
Ammonia, %CP	8.0–12.0	6.1	7.5	3.1	4.7	1.6	0.17

while rye had lesser yields with a slightly greater energy and protein content. There was no difference ($P = 0.10$) for CP yield across stages of maturity, however there was an effect of harvest maturity on DOM yield (Figure 4). The DOM yield increased from boot to pollination ($P = 0.05$), but pollination and milk did not differ ($P = 0.08$) and increased ($P < 0.01$) again at soft dough.

There were significant species by harvest interactions for pH, lactic acid, and total acid content. However, these differences were minor and inconsistent. Stage of harvest (Table 2) significantly affected the DM content, pH, lactic acid, acetic acid, and total acids content of the silage. The milk and soft dough stages did not require wilting prior to packing. However, despite wilting at boot and anthesis the silage DM content increased with maturity. Despite wilting, boot stage was still below the target DM content when packed. Despite this there was not an effect ($P = 0.24$) of stage on butyric acid content, suggesting that clostridial fermentation did not occur. In fact, boot stage appeared to have the best fermentation profile, obtaining a lower pH and greater lactic acid content than the later stages. There appeared to be only minor differences among the other stages.

Conclusion

These data suggest that planting rye or triticale results in the best nutrient yield per acre. If high quality forage is an operation's goal, harvesting at the pollination stage results in increased yield compared to boot without sacrificing a significant amount of nutritive value. For maximal energy yield per acre, waiting until soft dough may be the best option.

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Effect of Ad Libitum vs. Limit Feeding Program at Receiving on Morbidity and Performance of Feedlot Calves

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Summary with Implications

A two-phase study was conducted to determine the effects of two different feed delivery strategies during the receiving period of feedlot calves. Calves were fed either by limit-feeding at approximately 75% of ad libitum, or ad libitum feed offerings for the 30-d receiving period to determine effects on health and performance. During the receiving period, average daily gain and total weight gained was increased for the ad libitum treatment. No differences between ad libitum and limit-fed treatment groups were observed in either feed to gain or morbidity rates. During the second phase of the trial, a subset of calves was followed through finishing to observe the effect of the receiving strategies on the finishing period performance. At slaughter, no significant differences were observed between calves that were received on a limit-fed diet or fed ad libitum.

Introduction

Despite advancements in both vaccine technology and antibiotic therapy, bovine respiratory disease complex (BRD) remains the primary health challenge for cattle feeding operations in the United States. Consistently, those operations that struggle with BRD, do so during the period immediately following arrival of calves. As a rule, most of the morbidity and mortality observed occur in the first 30 to 60 days on feed. This naturally lends the question of how to address what appears to be an underlying systemic issue, independent of vaccine protocol design, that may help address and mitigate the occurrence of BRD during the receiving period. The strategy of limit feeding calves during the early receiving period has been proposed as one strategy to mitigate BRD risk nutritionally, but limited data support the use of such strategies, with most evidence being purely anecdotal. The objective of this study was to evaluate limit feeding as a receiving protocol to determine impact on pull rates, receiving performance, and overall finishing performance.

Procedure

Experiment 1

Steers originating from the Northern Plains (n = 704) were received at the Eastern Nebraska Research Extension and Education Center (ENREEC) feedlot in October of 2021 over a period of two weeks. Arrival processing protocol consisted of a commercial modified live 5-way viral vaccine with *Mannhemia haemolytica* and *Paseurella multocida* (Vista Once; Merck Animal Health, Omaha, NE), commercial 7-way clostridial with *Haemophilus somnus* (Vision 7 Somnus; Merck Animal Health, Omaha, NE), injectable dewormer (Dectomax; Zoetis Inc., Kalamazoo, MI), and placement of identification ear tags. Steers were processed at arrival and assigned randomly to pen and treatment; 16 calves were assigned to each pen to allow for adequate bunk space in both the limit-fed and ad libitum treatment groups. Pens were assigned randomly to treatment in a paired fashion to ensure that shared water tanks provided equal exposure to pathogen load across treatments. The treatments used in this study were ad-libitum feed delivery or limit-fed feed delivery of a single receiving diet consisting of 36% grass hay, 30% dry rolled corn, 30% Sweet Bran (Cargill, Inc., Blair, NE), and 4% supplement (DM basis). Calves on the limit-fed treatment were adapted to the diet upon arrival and limited to 2.2% of arrival body weight for the 30-day receiving period. Calves fed ad libitum were allowed to consume without restriction and diet was delivered according to bunk call. Calves were fed once daily in the morning; Steers were checked for health by a trained pen rider approximately 2 hours after feed delivery to allow for blinding to treatment by the animal health team. Calves were deemed a BRD case if they were pulled by the pen rider and subsequently met criteria for treatment upon presentation through the chute in the hospital (depression, anorexia, increased respiratory rate and/or effort, and rectal temperature greater than 103.5° F). At 28 d on feed, calves were limit-fed at 2% of BW for 5 days to equalize gut fill and subsequently weighed off the receiving portion of the trial by weighing two consecutive days prior to feeding. The average two-day weight was used as the final weight for the receiving trial, and the initial weight for the finishing trial. Pen was the experimental unit for statistical analysis.

Experiment 2

A subset of 222 steers in 14 pens were stepped up on finish ration after a 28-day receiving to evaluate potential carry-over effects on performance during finishing. The step-up period consisted of 5 step up ration over 23 days, and then a common finish ration consisting of 40% high moisture corn, 40% Sweet Bran (Cargill, Inc., Blair, NE), 15% corn silage, and 5% supplement. Steers were maintained in the same pen that they were housed in for the receiving phase. Cattle were implanted with Revalor IS (Merck Animal Health, Madison, NJ) at 40 d on feed and re-implanted at 130 d on feed with Revalor 200 (Merck Animal Health). Cattle were fed Optaflexx (Elanco Animal Health, Indianopolis, IN) during the last 28 d of the feeding period. All groups were harvested at a single time point at an average of 220 d from receiving. Hot carcass weight (HCW) and liver abscess score were collected at harvest; fat thickness (FT), longissimus muscle (LM) area, and marbling score were recorded after a 48-hour chill.

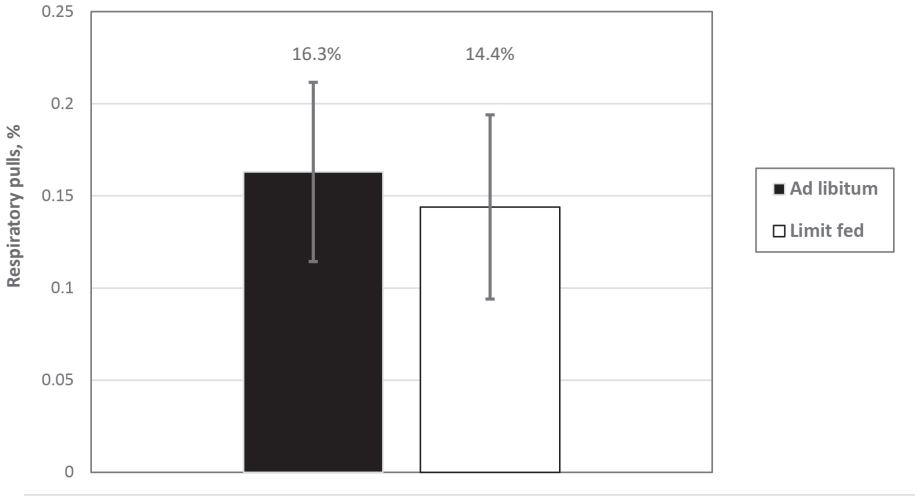

Fig. 1. Morbidity rates for ad libitum and limit-fed calves during the 28 day receiving period. Error bars represent the 95% confidence interval for incidence rate.

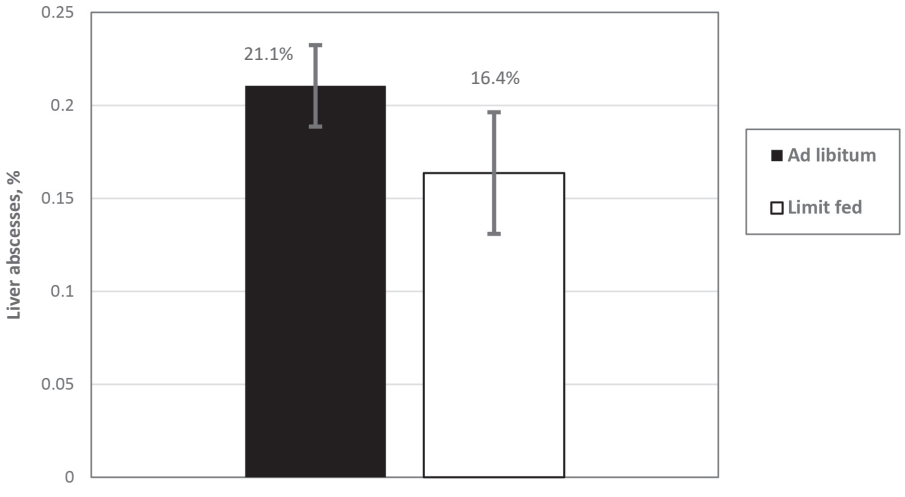

Fig. 2. Liver abcess incidence rate at harvest; error bars represent the 95% confidence interval for incidence rate of liver abscessation. P = 0.29.

Results

Experiment 1

Dry matter intake (DMI; $P < 0.01$), average daily gain (ADG; $P < 0.01$) and ending body weight ($P < 0.01$) were lower for the limit-fed treatment compared to ad libitum due to the limitation of intakes as designed (Table 1). Intake averaged 70.1% for limit-fed versus ad libitum whereas ADG was 72.6% for limit-fed compared to ad libitum. Because both DMI and ADG were decreased by similar amounts, F:G was not affected ($P = 0.28$). Numerically better F:G was observed for limit-fed cattle versus ad libitum but this 3.4% difference was not significant ($P = 0.28$). Morbidity rates for BRD were not statistically different due to treatment during the receiving period (ad libitum morbidity 16.3%; limit-fed morbidity 14.3%; $P = 0.58$, Figure 1), which may be due to statistical power. Mortality for the receiving period was 0.84% (3 hd) for the limit-fed treatment group, and 0% for the ad libitum treatment group, due to low mortality rates analysis was unable to be performed.

Experiment 2

When followed to harvest, there were no differences ($P > 0.18$) in ADG or DMI between treatments (Table 2). While not statistically different, there was a 2.2% increase in ADG for steers that were limit fed during the receiving period, which allowed HCW and final BW to be similar ($P = 0.39$) between the two receiving treatments. Carcass characteristics were also similar; where fat thickness ($P = 0.90$) and LM area ($P > 0.74$) did not differ between steers received with an ad libitum or limit-fed program (Table 2). No statistical difference ($P = 0.29$) in the rate or severity of liver abscess occurrence was noted. Incidence rate of liver abscesses in the ad libitum fed treatment was 21.05% with 3.7% incidence of A+ abscesses, LF treatment showed an incidence rate of 16.36%, and a 3.7% incidence of A+ abscesses (Figure 2).

Conclusion

Differences in intake and gain between receiving treatments did not affected DMI, ADG or F:G during the finish period. The strategy of limit-feeding new feedlot arrivals in order to decrease the incidence rate of BRD is not supported by these data. Discussions around the usefulness of limit-feeding as a management tool for BRD center around two questions: 1. Does limit-feeding have a mechanistic role in prevention of BRD (i.e., does it prevent calves from getting sick?); and/or 2. Does limit-feeding play a role in the selection bias of calves pulled by pen riders to be diagnosed as BRD and treated? This study was designed to evaluate question 1 by blinding pen riders to treatment and performing evaluations of health status away from feeding time. The lack of significant difference between treatments would lend us to conclude that limit-feeding on arrival does not play a mitigating role in the mechanism of development of BRD.

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Mitchell M. Norman, feedlot manager

Galen E. Erickson, professor, University of Nebraska-Lincoln

Table 1: Receiving period performance for ad libitum or limit fed calves during the 28- day receiving period.

	Ad Libitum[1]	Limit-Fed[1]	SEM	*P*-Value
Pens, (steers), n	22 (352)	22 (352)		
Initial BW, lb	577	577	3.2	0.89
End BW, lb	665	638	4.2	< 0.01
Gain, lb	86	62	1.8	< 0.01
DMI, lb/d	15.7	11.0	0.10	< 0.01
ADG, lb	2.80	2.03	0.058	< 0.01
F:G[2]	5.62	5.43	-	0.28

[1] AD = ad libitum fed calves at receiving, LF = limit-fed calves at receiving for first 38 days with intake targeted at a maximum of 2.2% of receiving body weight.

[2] F:G analyzed as G:F, the reciprocal

Table 2. Finishing performance of cattle received using either an ad libitum or limit-fed receiving protocol. Performance is for days 42 to 221.

	Ad Libitum[1]	Limit-Fed[1]	SEM	P-Value
Pens, (steers), n	7 (109)	7 (107)		
Initial BW, lb	665	638	4.2	*< 0.01*
Final BW[2], lb	1450	1430	7.9	*0.39*
DMI, lb/d	24.2	24.3	0.14	*0.21*
ADG, lb	4.01	4.10	0.049	*0.18*
F:G[3]	5.76	5.68	-	*0.42*
HCW, lb	927	921	5.1	*0.39*
FT, in	0.74	0.75	0.02	*0.9*
LM area, in[2]	14.9	14.9	0.16	*0.74*

[1] AD = ad libitum fed calves at receiving, LF = limit-fed calves at receiving for first 38 days with intake targeted at a maximum of 2.2% of receiving body weight.

[2] Final BW calculated from HCW utilizing a 64% standard dress.

[3] F:G analyzed as G:F, the reciprocal

Evaluation of Encapsulated *Megasphaera Elsdenii* in an Accelerated Beef Step-Up Program and an Acidosis Challenge Event

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Mitchell M. Norman
Tyler Spore
Mark Corrigan
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Summary with Implications

A 100-day metabolism study with 40 ruminally cannulated steers, individually fed, was conducted to determine the effects of daily feeding of encapsulated Megasphaera elsdenii along with a one-time dose of Lactipro NXT on dry matter intake, rumen organic acid concentration, lactate disappearance and native and specific strains of Megasphaera elsdenii concentration following an acidosis challenge. Steers fed Megasphaera elsdenii daily had greater intake after an acidosis event. Cattle fed daily Megasphaera elsdenii also had a faster rate of lactic acid disappearance after an acidosis event. Feeding Megasphaera elsdenii daily may result in a faster recovery time, after an acidosis event, compared to a one-time drench of Megasphaera elsdenii.

Introduction

Streptococcus bovis is a gram-positive bacterium that produces lactic acid, which causes a drop in ruminal pH below 4.8, the PKA of a volatile fatty acid (e.g. the pH at which a weak acid buffers). When cattle that are not adequately adapted to a high starch diet there can be an accumulation of lactic acid causing severe acidosis. In some animals, a single incident of ruminal acidosis has negative impacts throughout the entire finishing period, resulting in low feed intake and poor performance. Therefore, minimizing acidosis is important, especially during diet adaptation when acidosis is most prevalent. Traditionally, ruminants in the feedlot are stepped up gradually (3–4 weeks) from a high-forage to a high concentrate diet (HCD). A gradual increase of a HCD minimizes the accumulation of lactate in the rumen. In adequately adapted cattle the ruminal pH does not decrease below the ability of *Megasphaera elsdenii (M. elsdenii)* to convert lactic acid to volatile fatty acids. *Megasphaera elsdenii* is a lactate utilizing bacteria that has the potential to mitigate acidosis during the transition of feedlot cattle from a high-forage diet to HCD. The objective of this study was to evaluate the effects of a single LactiproNXT *(M. elsdenii)* drench or a LactiproNXT drench plus daily feeding of encapsulated *M. esldenii* at different rates during an accelerated step-up diet and following an acidosis challenge event.

Table 1. Dietary composition (% of DM) from step 1 diet through the finishing diet for all treatments

Ingredient	Step 1	Step 2	Step 3	Finisher
Steam-flaked Corn	37	52	62	70
MDGS	18	18	18	18
Alfalfa Hay	40	25	15	7
Supplement[1]				
Fine Ground Corn	2.202	2.202	2.202	2.202
Limestone	1.680	1.680	1.680	1.680
Urea	0.600	0.600	0.600	0.600
Salt	0.300	0.300	0.300	0.300
Tallow	0.125	0.125	0.125	0.125
Beef Trace Premix	0.050	0.050	0.050	0.050
Rumensin- 90 Premix[2]	0.165	0.165	0.165	0.165
Vitamin A-D-E	0.015	0.015	0.015	0.015
Tylan- 40 Premix[3]	0.011	0.011	0.011	0.011
Mcals,NEg/d	61.20	68.50	73.40	77.40

[1] Supplement fed at 5% of dietary DM for all treatments

[2] Supplement formulated to provide 30g/ton of Rumensin ® (Elanco Animal Health, DM Basis)

[3] Supplement formulated to provide 8.8g/ton of Tylan ® (Elanco Animal Health, DM Basis)

Procedure

A metabolism study conducted at the University of Nebraska—Lincoln Eastern Nebraska Research and Extension Center near Mead, NE, used 40 ruminally cannulated crossbred yearling steers [initial body weight (BW) = 958 ± 83.5 lb] Steers were sorted into two BW blocks, stratified by BW within block, and assigned randomly to one of five treatments (8 steers per treatment). Ground smooth bromegrass hay was offered at 2% of BW two weeks prior to experiment initiation to simulate steers received from pasture and to equilibrate gut fill to determine accurate initial BW.

Treatments consisted of control (Con) steers which were fed no *M. elsdenii* and stepped onto the finishing ration over 19 days. LactiproNXT (Drench) steers were drenched with the commercial dose of LactiproNXT on d 1 of the experiment and received no other *M. elsdenii*. LactiproNXT+10^6 (Low) steers were drenched with the commercial dose of LactiproNXT on d 1 of the experiment and received 1×10^6 CFU of encapsulated *M. elsdenii* daily throughout the experiment. LactiproNXT+10^7 (Medium) steers were

Table 2. Dry matter intake (as pounds)

	Treatments						*P*-value			
Item	Control	Drench	Low	Medium	High	SEM	Control vs Mega E	Drench vs Daily	Linear	Quadratic
Step-up DMI, lb[1]	21.1	20.8	20.9	20.8	20.3	0.60	0.51	0.84	0.70	0.45
Step-up DMI, Mcals Neg/d[2]	15.3	15.4	16.3	15.1	15.4	0.5	0.12	0.32	0.42	0.42
Finishing period DMI, lb[3]	28.9	26.7	27.9	28.2	27.6	1.2	0.36	0.48	0.69	0.16
Challenge DMI, lb[4]	45.4	43.6	47.4	46	48.1	3.0	0.76	0.30	0.30	0.99
Recovery DMI, lb[5]	22.9	19.4	26.5	23.7	23.9	2.5	0.85	0.07	0.11	0.26
Recovery DMI, % of pre-challenge intake[6]	78.3	68.8	88.7	83.2	86.9	7.7	0.64	0.05	0.06	0.57

[1] DMI for d 1–19

[2] DMI for d 1–19 expressed as Mcals of net energy for gain per day

[3] DMI for d 20–88

[4] DMI for d 90

[5] DMI for d 91, 92, and 93

[6] Recovery DMI, % of pre-challenge intake, is expressed as % of the average intake of the 9 days immediately prior to challenge

Table 3. Disappearance of Lactate over time from rumen fluid collected on d 88

	Treatments					*P*-value		
Incubation time, h	Control	Drench	Low	Medium	High	Treatment	Hour	Treatment x Hour
0	3.30[1]	3.34	3.26	3.24	3.27	0.13	<0.01	0.18
12	2.85[a]	2.94[a]	2.21[b]	1.85[b]	1.97[b]			
24	0	0	0	0	0			

[a,b] Means within a row that lack a common superscript differ (P ≤ 0.05).

[1] Lactate values are reported in mmol of lactate.

Table 4. Disappearance of Lactate over time from rumen fluid collected on d 90, 91, and 92

	Treatments					*P*-value[2]		
Incubation time, h	Control	Drench	Low	Medium	High	Treatment	Hour	Treatment x Hour
0	3.30[1]	3.28	3.29	3.26	3.26	0.14	<0.01	0.01
12	2.31[a]	2.16[ab]	1.88[b]	1.21[c]	1.77[b]			
18	0.23	0.52	0.65	0.30	0.20			

[a,b] Means within a row that lack a common superscript differ (P ≤ 0.05).

[1] Lactate values are reported in mmol of lactate.

[2] The model included day as the repeated measure animal as the subject, and compound symmetry as the covariance structure The Treatment × Day × Hour interaction was tested before selecting the repeated model (*P* = 1.00).

drenched with the commercial dose of LactiproNXT on d 1 of the experiment and received 1×10^7 CFU of encapsulated *M. elsdenii* daily throughout the experiment. LactiproNXT+10^8 (High) steers were drenched with the commercial dose of LactiproNXT on d 1 of the experiment and received 1×10^8 CFU of encapsulated *M. elsdenii* daily throughout the trial. Treatments of Drench, Low, Medium, and High were stepped up to the finishing ration over 9 days. Steers were individually fed for 100 days in the Calan gate system. Diet and supplement composition are shown in Table 1. The diet contained 5% supplement and all supplements were formulated to include 30 g/ton of monensin (Rumensin®, Elanco Animal Health, Greenfield, IN) and 8.8 g/ton of tylosin (Tylan®, Elanco Animal Health). Steers were fed once daily at 0700 h and had ad libitum access to water. The experiment included five continuous phases: step-up period (d 1–19); finishing period (d 20–88); feed restriction (d 89, 24-h full feed restriction); challenge period (d 90, cattle were fed at 150% of max DMI from finishing period); and recovery period (d 91–96). Feed refusals were collected every 3 days during the step-up period, every 7 days during the finishing period, and every day during challenge and recovery periods. Samples were collected at 0600 h and dried in a forced-air oven to correct for dry matter (DM) to determine dry matter intake (DMI). Rumen fluid samples were collected every 3 days in the step-up period, every 7 days in the finishing period, and every day during challenge and recovery periods at 1300 h. During the challenge and recovery periods (d 88, 90, 91, 92), a small tube of rumen fluid collected was retained at room temperature and 0.1 mL of the fluid was

injected into glass tubes containing a lactate culture to estimate lactate disappearance. A total of three tubes per day per animal were injected at 1400 h. Tubes were incubated in a 38°C water bath for either 0, 12, and 24 h for d 88 and for d 90–92 at 0, 12, and 18h, then frozen for analysis of lactate using gas chromatography.

Repeated measures were used within three phases of step-up period (d 1–19), finishing period (d 20–88), and recovery period (d 91–93). However, challenge period (d 90) was not repeated since it was only one day. Data were tested for linear and quadratic effects of dose with drench as the intercept. Data were tested for linear and quadratic effects of time tested and time × treatment interaction tested using covariate regression. The following contrast were reported control vs Lactipro (cattle fed any *Megasphaera elsdenii)* and drench vs daily (low, medium, and high treatments). Proc IML was used to get contrast coefficient for unequal spacing. Statistical significant was declared at $P \leq 0.10$ and a tendency $P \leq 0.15$.

Results

Intake

In the step-up period (d 1–19), there were no significant linear, quadratic, or contrasts between treatments; however, there was a tendency for steers fed M. *elsdenii* to have greater intake of NE_g per day ($P = 0.12$, Table 2) because they were stepped up to the HCD in 9 d vs. 18 d. Throughout the finishing period (d 20–88) and on the challenge day (d 90) there were no significant differences in DMI. However, steers fed *M. elsdenii* daily had greater DMI during recovery period (d 91–93; $P \leq 0.07$), as well as a tendency for a linear increase in DMI with increasing the dose of *M. elsdenii* ($P = 0.11$), primarily due to the low DMI during the recovery period by steers receiving only the drench. When recovery of pre-challenge intake is expressed as a percentage of the average intake of the 9 days immediately prior to challenge, there was a higher % DMI for cattle fed *M. elsdenii* daily compared to the one-time drench ($P \leq 0.05$, Table 2).

Lactic Acid Disappearance

Disappearance of lactic acid was measured on d 88 (pre-challenge), d 90 (challenge day), and d 91–92 (recovery days). On d 88 there was no significant treatment × hour effect, however, there was a significant hour effect ($P < 0.01$, Table 3) and a tendency for a treatment effect ($P \leq 0.13$). There were greater rates of disappearance of lactate for cattle fed *M. elsdenii* daily compared to the one-time drench. On d 90, 91, and 92 there were no effects of treatment × day × hour or treatment day ($P = 1.00$, Table 4). There was an hour ($P < 0.01$) and treatment × hour effect ($P \geq 0.01$).

Conclusion

These results suggest that the one-time LactiproNXT drench does not last up to 90 days in the rumen. Steers fed *Megasphaera elsdenii* 41125 daily, tended to have a greater DMI after the acidosis event occurred. The daily dosed steers consumed more feed sooner after an off-feed event, which suggest that the daily feeding *M. elsdenii* can be beneficial to a feed yard on days where there can be an off-feed event. However, daily feeding of *M. elsdenii* appeared to impact outcomes regardless of the amount that it was fed. When an acidosis event occurs, cattle fed *M. elsdenii* daily, may have greater utilization of lactate, which could contribute to faster intake recovery at the bunk.

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Evaluation of LactiproFLX in an Acidosis Challenge Model

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Summary with Implications

An acidosis challenge study was conducted comparing different administration techniques for LactiproFLX, a direct fed microbial product containing Megasphaera elsdenii (a lactate-utilizing bacteria) for the prevention of acidosis. Four treatments were utilized in a randomized block design with 24 ruminally cannulated steers. Treatments consisted of a control group which did not receive the product, a group which received the commercial dose of the product four days before the acidosis challenge, one which received the commercial dose of the product one day before the challenge, and one which received ten times the commercial dose one day before the challenge. No differences were detected for rumination time or dry matter intake. Similarly, no differences were detected in the millimolar (mM) concentrations of propionate, valerate, or isovalerate. Several differences, however, were detected for total volatile fatty acids (VFA), acetate, isobutyrate, and butyrate during different periods of the study. Additionally, several differences were detected for ruminal pH parameters with the treatment dosed 4 days before the challenge having the greatest minimum and maximum pH when compared to the other treatments. The group dosed with ten times the commercial dose displayed lower pH variance and magnitude of change when compared to the other treatments. Therefore, if using exogenous Megasphaera elsdenii as an acidosis mitigation strategy, giving the bacteria time to establish in the rumen before an acidotic event could increase the effectiveness of the treatment. If giving the treatment closer to a possibly acidotic event, giving a higher dose could be beneficial.

Introduction

With acidosis being a risk to cattle fed high concentrate diets, considerable efforts have been made to reduce the incidence and severity of acidotic events in the feedlot industry. One of those efforts has been the development of LactiproFLX, a direct-fed microbial product containing a specific strain of lactic acid-utilizing bacteria (*Megasphaera elsdenii* NCIMB 41125; MS Biotech). The dose and administration type used depends on the production system and reason for use, but the product can provide from 5.0×10^9 to 1.0×10^{10} CFU of this bacterium.

Although lactic acid is not generally present in high amounts in the rumen under normal circumstances, certain events such as the step-up period, severe weather events, and illness can cause increased potential for lactic acid accumulation during acidosis in feedlot cattle. Because *Megasphaera elsdenii* utilizes lactic acid in the rumen, much of the interest in the research community has been focused on using it for acidosis mitigation. The theory behind the use of this bacteria for acidosis mitigation relates to the control of lactic acid concentrations in the rumen post-feeding, thereby slowing the decline of rumen pH.

The objective of this study was to evaluate the effects of 3 administration techniques of LactiproFLX compared to a control group in an acidosis challenge model.

Procedure

An acidosis challenge study was conducted using 24 ruminally cannulated steers in a randomized block design containing four treatments with 6 steers per treatment. Steers were blocked by weight, stratified by average intake within weight block, and assigned randomly to treatment. Three blocks of 8 steers were used with weight blocks being light, medium, and heavy. Treatments consisted of a control group which received no LactiproFLX (CON), a group which received the commercial dose of LactiproFLX (1.0×10^{10} CFU) 4 days prior to the acidosis challenge (COMM-4), a group which received the commercial dose of LactiproFLX one day prior to the challenge (COMM), and a group which received 10 times the commercial dose of LactiproFLX (1.0×10^{11} CFU) one day prior to the challenge (10X). All LactiproFLX capsules were dosed via the rumen cannula. Each block consisted of an experimental period which was 20 days in length and each treatment was represented by two animals in each block.

All animals were stepped up onto the finishing diet and fed for at least 32 days prior to the initiation of the experimental period. Diet and supplement composition are presented in Table 1. The supplement used was formulated to include 30 g/ton monensin (Rumensin, Elanco Animal Health) and provide 90 mg/steer daily of tylosin (Tylan, Elanco Animal Health). Steers were fed to target *ad libitum* intake

Table 1. Dietary composition for all treatments

Ingredient	DM Inclusion (%)
Steam-flaked corn	68
Modified distillers' grains	18
Alfalfa hay	9
Supplement[1]	
Fine ground corn	2.32
Limestone	1.67
Tallow	0.125
Urea	0.5
Salt	0.3
Vitamin A-D-E Premix	0.05
Beef Trace Premix	0.015
Rumensin Premix[2]	0.017
Tylan Premix[3]	0.003

[1]Supplement included in the diet at 5% DM

[2]Formulated to supply 30 g/ton DM of Rumensin

[3]Formulated to provide 90 mg per steer daily of Tylosin

Table 2. Dry matter intake of diet by treatment

	Treatment					*P*-value		
Item	CON	COMM	COMM-4	10X	SEM	TRT	Day	TRT*Day
DMI								
Overall, lb[1]	21.2	21.4	21.5	22.0	0.44	0.62	<0.01	0.82
Pre-challenge, lb[2]	20.5	21.8	21.2	21.1	0.52	0.34	<0.01	0.73
Challenge, lb[3]	32.5	31.4	33.8	35.1	1.77	0.50	-	-
Day 1, lb	15.2	13.6	16.4	16.3	2.14	0.77	-	-
Recovery, lb[4]	21.1	20.4	20.0	21.3	1.16	0.52	<0.01	0.64

[1]Values represent average intake over entire period from day -6 through 5 (excluding -1)

[2]Values represent average intake for days -6 through -2

[3]Values represent average intake for the acidosis challenge day (Day 0) only

[4]Values represent average intake for days 2 through 5

Table 3. Time spent ruminating

	Treatment					*P*-value		
Item	CON	COMM	COMM-4	10X	SEM	TRT	Day	TRT*Day
Rumination, min/day								
Pre-challenge[1]	297	270	232	266	35.8	0.66	0.01	0.38
Restriction[2]	228	261	207	256	45.5	0.82	-	-
Challenge[3]	114	121	114	147	17.3	0.48	-	-
Recovery[4]	187	202	140	182	28.2	0.47	<0.01	0.06
Overall[5]	238	229	175	219	29.8	0.21	<0.01	0.29

[1]Prechallenge period consisted of days -6 through -2

[2]Restriction period consisted of day -1

[3]Challenge period consisted of day 0

[4]Recovery period consisted of days 1 through 5

[5]Overall data included days -6 through 5

and fed twice daily at 0700 h and 1300 h. Unlimited access to water was provided. Feed refusals were collected and weighed daily to calculate daily DMI. Cattle were housed in a temperature-controlled room in individual pens equipped with rubber slatted floors. Rumen pH was measured continuously during the experimental period using SmaXtec wireless pH probes and averaged by hour. Minimum, maximum, average, magnitude of change, and pH variance were calculated by day. The number of minutes spent ruminating was continuously measured using CowManager sensor eartags and summarized by day.

During the experimental period, animals had *ad libitum* access to feed until 1900 h on day -2 (two days prior to the challenge) when feed was removed from the bunk to create a 36-h feed restriction period. Animals were only offered 50% of their 7-day average intake on day -1 (restriction day). On d 0, or the challenge day, steers were offered 175% of their average intake. On day 1, animals were offered their previous average intake, and on day 2, normal bunk reading protocols resumed. Rumen fluid samples were taken at 0700 h and 1100 h on day -2 and at 0700, 1100, and 1700 h on days 0, 1, and 2. Rumen contents were collected through the rumen cannula, strained through cheesecloth, and flash frozen in liquid nitrogen for analysis of volatile fatty acid (VFA) concentrations using gas chromatography.

All data were analyzed using a mixed procedure of SAS as a randomized block design with animal as the experimental unit. For DMI and rumination, data were summarized as overall (days -6 through 5), pre-challenge (days -6 through -2), challenge (day 0), day 1, and recovery (days 2 through 5). The periods containing multiple days (overall, pre-challenge and recovery) were analyzed with treatment, day, and treatment by day interaction included in the model, with day considered a repeated measure. All periods for the pH parameters used a similar model in SAS, as all periods were multiple days. For volatile fatty acid concentration, all periods but the restriction period, used a similar model as above but utilized time of collection as the repeated measure instead of day. Each period (except restriction) contained multiple samples taken at different times. Interactions and treatment differences were declared significant at $P \leq 0.05$ and a tendency was considered at $0.05 \leq P \leq 0.10$.

Results

Dry matter intake and rumination

No significant treatment differences or interactions were detected for overall dry matter intake (DMI) ($P = 0.74$) or for intake during any periods of the experiment ($P \geq 0.34$; Table 2). This was unexpected as it was hypothesized that intake would recover more rapidly for Lactipro treated cattle after the challenge. Time spent ruminating

Table 4. Minimum, maximum, average, standard deviation, and magnitude of change of ruminal pH

	Treatment					*P*-value		
Item	CON	COMM	COMM-4	10X	SEM	TRT	Day	TRT*Day
Minimum pH								
Pre-challenge[1]	5.70[b]	5.64[b]	5.99[a]	5.76[ab]	0.100	0.09	0.23	0.11
Challenge[2]	5.09[bc]	5.04[c]	5.47[a]	5.41[ab]	0.145	0.10	<0.01	0.56
Recovery[3]	5.64	5.49	5.85	5.53	0.127	0.17	0.38	0.46
Overall[4]	5.57[b]	5.50[b]	5.89[a]	5.64[b]	0.078	<0.01	<0.01	0.14
Maximum pH								
Pre-challenge	6.72	6.67	6.93	6.62	0.136	0.37	0.02	0.89
Challenge	6.42	6.44	6.68	6.48	0.164	0.66	0.71	0.15
Recovery	6.30[b]	6.54[b]	6.90[a]	6.25[b]	0.156	0.02	<0.01	0.11
Overall	6.57[b]	6.61[b]	6.97[a]	6.38[b]	0.116	0.01	<0.01	0.38
Average pH								
Pre-challenge	6.15	6.24	6.41	6.24	0.132	0.57	<0.01	0.05
Challenge	5.55	5.56	5.87	5.79	0.142	0.30	0.02	0.50
Recovery	6.01	5.93	6.21	5.93	0.141	0.44	0.20	0.78
Overall	6.06	5.99	6.31	6.04	0.097	0.11	<0.01	0.18
pH Variance								
Pre-challenge	0.31	0.27	0.27	0.25	0.021	0.32	0.54	0.51
Challenge	0.36[ab]	0.41[a]	0.35[b]	0.30[b]	0.027	0.05	<0.01	0.26
Recovery	0.20[b]	0.25[ab]	0.28[a]	0.19[b]	0.025	0.05	<0.01	0.16
Overall	0.28	0.29	0.28	0.24	0.014	0.12	<0.01	0.14
pH Magnitude								
Pre-challenge	1.09	0.98	0.89	0.89	0.068	0.16	0.24	0.48
Challenge	1.27[bc]	1.45[ab]	1.23[bc]	1.06[c]	0.092	0.06	<0.01	0.38
Recovery	0.82[b]	0.97[ab]	1.02[a]	0.66[b]	0.084	0.03	0.14	0.33
Overall	1.04[a]	1.06[a]	0.97[ab]	0.86[b]	0.049	0.04	<0.01	0.26

[a-d]Means in a row with different superscripts are different ($P < 0.10$)

[1]Pre-challenge period consists of days -6 through -2

[2]Challenge period consists of days 0 and 1

[3]Recovery period consists of days 2 through 5

[4]Overall includes all days

was not different among treatments during any period of the experiment ($P > 0.20$; Table 3). There was a treatment by time interaction for the recovery period where the COMM-4 treatment did not increase rumination at the same rate as all other treatments following the challenge ($P = 0.06$; Table 3).

Rumen pH

The effects of treatment on ruminal pH are presented in Table 4. No significant treatment effects were detected for the pre-challenge period for maximum, average, variance, or magnitude of change in rumen pH ($P \geq 0.16$). There were tendencies for treatments to differ for minimum pH during the pre-challenge ($P = 0.09$) and challenge periods ($P = 0.10$). For the pre-challenge period the COMM-4 treatment had the greatest minimum pH, CON and COMM groups had lowest pH, and 10X group was intermediate. The challenge period displayed similar results. The overall minimum pH was also significantly different between treatments with the COMM-4 group having the greatest pH when compared to all other treatments ($P < 0.01$). No statistical difference was detected for pH due to treatment during the recovery period ($P = 0.17$).

Maximum pH was also impacted by treatment for the recovery ($P = 0.02$) and overall periods ($P = 0.01$). During the recovery and overall periods, the COMM-4 treatment group had a greater maximum pH than all other treatments. For average pH, the only statistical difference was a significant treatment by time interaction for the pre-challenge period ($P = 0.05$). This was due to an increasing average pH for the CON and 10X groups, and a decrease for COMM-4 and CON groups as the days of the experiment progressed (days -6 through -2).

Significant differences were also detected for pH variance during the challenge ($P = 0.05$) and recovery periods ($P = 0.05$) only. For the challenge period, the COMM group had the greatest variance, 10X and COMM-4 the lowest variance, and CON was intermediate. During the recovery period, COMM-4 had the largest variance,

with CON and 10X had the least, and COMM was intermediate. Several significant differences were also detected between treatments for magnitude of change in pH for all periods except pre-challenge. During the challenge period, the COMM group had the largest magnitude of change, 10X the least, and CON and COMM-4 were intermediate ($P = 0.06$). In the recovery period, the COMM-4 group had the greatest magnitude of change, CON and 10X the lowest, and the COMM group remained intermediate ($P = 0.03$). Finally, the overall magnitude of change was greatest for the CON and COMM treatments, lowest for the 10X group, and intermediate for the COMM-4 treatment ($P = 0.04$).

Volatile fatty acid concentration

No significant interactions or treatment differences were found for propionate, valerate, or isovalerate during any of the periods ($P \geq 0.10$; Table 5). Similarly, no interactions or treatment differences were detected for the pre-challenge or restriction periods for total volatile fatty acids (VFA), acetate, or isobutyrate. There was a tendency for treatment to affect total VFA concentration with the COMM group having the greatest concentration, COMM-4 being intermediate, and CON and 10X having the lowest ($P = 0.10$). No other treatment effects or interactions were detected for total VFA. For butyrate, a significant difference for treatment was found during the pre-challenge period, with the COMM-4 group being statistically greater than the other 3 treatment groups ($P = 0.02$; Table 5). This was to be expected as one product of lactic acid fermentation by *Megasphaera elsdenii* is butyrate. The COMM-4 group was dosed 4 days prior to the challenge, which means theoretically, that group should have contained a larger population of *Megasphaera elsdenii* in the rumen at these time points than the other treatments. There was also a tendency for a treatment by time interaction for butyrate during the challenge period ($P = 0.08$). No significant differences were detected during the other periods for butyrate. There was also a tendency for the COMM group to have a lower acetate concentration than the 10X or CON groups with COMM-4 being intermediate ($P = 0.07$; Table 5). A tendency for an interaction for isobutyrate during the challenge period was also detected ($P = 0.08$; Table 5). The CON group had a slower decline in isobutyrate across time than the other 3 treatments with the COMM group having the lowest average concentration of isobutyrate, the 10X and CON groups having the highest concentrations, and COMM-4 being intermediate (Table 5). Interestingly, there was also a significant treatment effect for isobutyrate during the recovery period with the COMM-4 group having a lower concentration compared to the other three treatments ($P = 0.04$; Table 5). No significant differences were found for the pre-challenge or restriction phases for isobutyrate ($P \geq 0.51$).

Conclusion

Results from this study suggest that LactiproFLX administered using the techniques above had no impact on dry matter intake or rumination. Several differences were observed for ruminal pH parameters. The COMM-4 group was able to maintain greater minimum and maximum pH for the overall period analysis, indicating this administration method could help prevent acidosis. The statistical differences for magnitude of change for pH and pH variance were more complex. However, the 10X group appeared to have lower variance and magnitude of change during the challenge and recovery periods, suggesting this treatment administration method could lessen the variation in daily pH.

The product affected the concentration of some VFAs in the rumen fluid with isobutyrate, butyrate, and acetate being altered by treatment. Notably, the COMM-4 treatment had a much greater butyrate concentration during the pre-challenge period, suggesting that the *Megasphaera elsdenii* dosed 4 days prior to the challenge was able to survive in the rumen and establish a population before the challenge period.

Overall, LactiproFLX had no effect on the intake and rumination parameters measured in this experiment, although the experimental design may not allow for significant power to detect differences in DMI. However, several ruminal pH measurements in this experiment were different among treatments with the COMM-4 group having the greatest minimum and maximum pH, and the 10X group having the lowest pH variance and magnitude of change suggesting these two administration methods could be the most effective at preventing acidosis.

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Table 5. The mM concentration of volatile fatty acids from collected rumen fluid

	Treatment					*P*-value		
Item	CON	COMM	COMM-4	10X	SEM	TRT	Time	TRT*Time
Acetate								
Pre-challenge[1]	51.88	55.42	56.37	52.68	3.876	0.82	<0.01	0.82
Restriction[2]	30.88	29.16	30.34	26.40	2.942	0.71	-	-
Challenge[3]	76.75	81.09	80.12	71.10	3.760	0.26	<0.01	0.23
Recovery[4]	73.08^{b}	64.38^{a}	68.42^{ab}	73.48^{b}	2.765	0.07	<0.01	0.87
Propionate								
Pre-challenge	53.32	57.44	56.06	55.23	5.552	0.96	<0.01	0.53
Restriction	15.99	16.56	13.81	10.78	2.794	0.47	-	-
Challenge	71.09	85.84	71.83	68.84	5.876	0.17	<0.01	0.18
Recovery	93.89	86.88	87.00	94.38	5.274	0.60	<0.01	0.78
Isobutyrate								
Pre-challenge	1.40	1.32	1.30	1.16	0.115	0.51	0.06	0.48
Restriction	1.06	0.94	1.02	0.95	0.090	0.74	-	-
Challenge	0.89^{b}	0.63^{a}	0.79^{ab}	0.88^{b}	0.075	0.08	0.89	0.08
Recovery	1.11^{b}	1.04^{b}	0.89^{a}	1.09^{b}	0.064	0.04	<0.01	0.15
Butyrate								
Pre-challenge	5.60^{a}	6.40^{a}	9.60^{b}	6.17^{a}	0.859	0.02	<0.01	0.33
Restriction	2.16	2.46	3.13	2.86	0.401	0.36	-	-
Challenge	9.72	11.50	13.42	11.55	1.559	0.44	<0.01	0.08
Recovery	8.71	9.60	8.84	9.58	1.107	0.87	0.43	0.48
Isovalerate								
Pre-challenge	1.14	1.15	1.05	1.02	0.182	0.94	0.45	0.71
Restriction	1.44	0.95	1.82	1.94	0.408	0.34	-	-
Challenge	1.34	0.95	1.47	1.52	0.348	0.65	0.36	0.02
Recovery	1.09	0.95	1.09	0.84	0.172	0.68	<0.01	0.56
Valerate								
Pre-challenge	2.17	2.62	2.86	1.78	0.643	0.65	<0.01	0.11
Restriction	0.41	0.56	0.60	0.51	0.177	0.88	-	-
Challenge	4.13	4.88	4.81	4.24	0.512	0.53	<0.01	0.19
Recovery	4.56	4.81	5.03	4.62	0.666	0.94	0.48	0.78
Total								
Pre-challenge	115.50	124.29	127.24	118.05	8.859	0.77	<0.01	0.31
Restriction	51.93	50.63	50.52	43.46	5.763	0.73	-	-
Challenge	164.80^{a}	185.32^{b}	172.53^{a}	156.61^{a}	7.935	0.10	<0.01	0.12
Recovery	181.47	168.10	170.04	185.73	8.296	0.34	<0.01	0.84

[a-d]Means in a row with different superscripts are different ($P < 0.10$)

[1]Pre-challenge period consisted of samples taken at 0700 h and 1100 h on day -2

[2]Restriction period consisted of one sample per animal taken at 0700 h on day 0 (before feeding).

[3]Challenge period consisted of samples taken at 1100 h and 1700 h on day 0 and 0700 h on day 1.

[4]Recovery period consisted of samples taken at 1100 h and 1700 h on day 1 and 0700h, 1100 h, and 1700 h on day 2

Effects of Individual Sweet Bran Components in Beef Finishing Diets on Nutrient Digestion

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Summary with Implications

Sweet Bran is a branded wet corn gluten feed recognized for improving rumen health, energy intake, and gains in finishing cattle. Eight ruminally cannulated steers were utilized in a replicated 4 × 4 Latin Square design to evaluate the effect of individual Sweet Bran components on total tract digestibility and rumen fermentation parameters. Three Sweet Bran components (solvent extracted germ meal, corn bran, and mixed steep) were included at 40% of diet dry matter in their respective treatment, with a steam-flaked corn control diet. Total tract dry matter and organic matter digestibility were least for bran, intermediate for solvent extracted germ meal, and greatest for steep and control diets. Neutral detergent fiber digestibility was least for control and intermediate for bran and steep with a tendency for solvent extracted germ meal to have the greatest fiber digestibility. Overall, steep and solvent extracted germ meal have similar energy densities as the steam-flaked corn control, and bran and solvent extracted germ meal are highly digestible fiber sources. The nutrient and physical characteristics of steep, solvent extracted germ meal, and bran are complementary and may contribute to the greater energy value of Sweet Bran compared to dry-rolled corn.

Introduction

Wet corn gluten feed is a common by-product from the wet corn milling process but can vary in nutrient composition and feeding value based on the level of corn bran, mixed steep, and solvent extracted germ meal (SEM) in the mixture. Corn bran is the highly digestible, fibrous portion of the corn kernel. During the manufacturing of corn gluten feed, wet bran is pressed and may be dried before the addition of steep. Mixed steep is a mixture of heavy steep water and distiller's solubles and contains amino acids, minerals, and vitamins as well as fermentation end products such as lactate. Solvent-extracted germ meal is the fraction remaining after oil is extracted from the germ.

Sweet Bran is a branded corn gluten feed consisting of corn bran, mixed steep, and SEM and recognized for a consistent supply and nutrient composition. Incorporation of bran, steep, and SEM in Sweet Bran may vary, within feed label requirements, resulting in slight changes to ingredient proportions. Therefore, the objective of this digestion study was to evaluate the effect of individual Sweet Bran components, corn bran, SEM, and steep, on total tract nutrient digestion and rumen fermentation parameters.

Table 1. Diet composition (DM basis) fed to steers to evaluate nutrient digestion of individual Sweet Bran components

	Treatment[1]			
Ingredient	CON	SEM	BRAN	STEEP
Steam-flaked corn	79	40	40	40
Solvent extracted germ meal	-	40	-	-
Dry corn bran	-	-	40	-
Steep liquor	-	-	-	40
Corn silage	15	15	15	15
Supplement[2]				
Fine ground corn	0.305	2.83	1.33	1.86
Soybean meal	2.0	-	-	-
Limestone	1.66	1.66	1.66	2.63
Tallow	0.15	0.125	0.125	0.125
Urea	1.5	-	1.5	-
Salt	0.3	0.3	0.3	0.3
Vitamin A-D-E premix	0.015	0.015	0.015	0.015
Beef trace premix	0.05	0.05	0.05	0.05
Rumensin premix[3]	0.017	0.017	0.017	0.017
Tylan premix[4]	0.0035	0.0035	0.0035	0.0035
Analyzed nutrient composition, %				
Organic matter	96.82	96.33	96.78	91.75
Neutral detergent fiber	10.59	23.49	32.16	8.00
Crude protein	12.02	14.58	14.04	29.28
Starch	62.59	43.12	39.68	35.39

[1]Treatments included CON- control, SEM-solvent extracted germ meal, BRAN- corn bran, STEEP-mixed steep

[2]Supplement fed at 6% for CON treatment and 5% for SEM, BRAN, and STEEP.

[3]Formulated to supply Rumensin-90 (Elanco Animal Health) at 30 g/ton DM.

[4]Formulated to supply Tylan-100 (Elanco Animal Health) at 90 mg per steer daily.

[5]Individual feed ingredients analyzed for nutrient composition

Procedure

Eight ruminally cannulated crossbred steers were used in a replicated 4 x 4 Latin

square design with 21-d periods consisting of a 16-d adaptation period followed by a 5-d sample collection period. The study was conducted over 84 d. There were four dietary treatments in an unstructured treatment design: 1) control (CON) consisting of 80% steam-flaked corn (SFC), 2) solvent extracted germ meal (SEM), 3) dried corn bran (BRAN), and mixed steep (STEEP), included at 40% of diet dry matter with 40% SFC (Table 1). All the dietary treatments contained 15% corn silage and 5% supplement, except for the control. The control treatment contained 6% supplement with soybean meal to meet protein requirements and equalize protein content among dietary treatments. All supplements were formulated to include 30 g/ton of monensin (Rumensin, Elanco Animal Health) and 8.8 g/ton of tylosin (Tylan, Elanco Animal Health).

Steers were fed twice daily at 0700 h and 1300 h and had ad libitum access to feed and water. Cattle were housed in individual, rubber slatted pens in a temperature-controlled room. Ingredient samples were taken during the collection period at the time of mixing, composited by period, freeze-dried and ground through a Wiley Mill using a 1-mm screen. Feed refusals were collected on d 18 and 19 before feeding, dried in a forced air oven, ground through a Wiley Mill using a 1-mm screen, and composited by steer within collection period. Beginning on d 7 of each period, titanium dioxide was dosed intraruminally at 0700 and 1700 h to provide a total of 20 g/d. Fecal samples were collected at 4 times/d at 0700, 1100, 1500, 1900, 2300, and 0300 h on d 19 and 20. Fecal samples were composited by day, freeze-dried, ground as previously described, and composited by animal within period. Fecal samples were analyzed for titanium dioxide to determine fecal output and nutrient digestibility. Feed ingredients, feed refusals, and fecal samples were analyzed for dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), total starch, and crude protein (CP).

Ruminal pH was measured continuously throughout the trial with SmaXtec wireless pH probes. Measurements for pH included average ruminal pH, minimum and maximum pH, magnitude of change, and variance. The number of minutes spent ruminating was also continuously measured using CowManager Sensor ear-tags.

Table 2. Nutrient intake and digestibility of steers fed individual Sweet Bran components

	Treatment[1]					
Item	CON	SEM	BRAN	STEEP	SEM	*P*-value
DM						
Intake, lb	24.8	23.8	25.5	25.6	0.95	0.15
Digestibility, %	82.24^{c}	77.45^{b}	68.97^{a}	84.24^{c}	2.02	<0.01
OM						
Intake, lb	22.3	22.0	23.6	21.9	1.31	0.51
Digestibility, %	83.00^{c}	78.56^{b}	69.56^{a}	86.30^{c}	1.75	<0.01
NDF						
Intake, lb	2.41^{a}	5.13^{b}	7.73^{c}	1.82^{a}	0.34	<0.01
Digestibility, %	20.96^{a}	52.69^{b}	37.03^{b}	37.62^{b}	6.14	0.02
Starch						
Intake, lb	15.23^{a}	9.96^{b}	9.50^{b}	8.83^{b}	0.66	<0.01
Digestibility, %	99.49	99.10	99.04	99.36	0.19	0.16
DE						
Apparent energy digestibility, %	81.58^{bc}	76.57^{b}	67.96^{a}	85.55^{c}	2.13	<0.01
DE, Mcal/d	38.45^{b}	35.82^{ab}	33.42^{a}	41.59^{c}	1.52	<0.01
DE, Mcal/lb	7.54^{b}	7.32^{b}	6.44^{a}	7.89^{b}	2.01	<0.01

^{abc}Means in a row with different superscripts are different ($P < 0.05$)

[1]Treatments included CON- control, SEM-solvent extracted germ meal, BRAN- corn bran, STEEP-mixed steep

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc.) with period, treatment, and steer within square as fixed effects. Ruminal pH was analyzed using the MIXED procedure of SAS with treatment, hour, treatment by hour interaction included in the model and hour being considered a repeated measure. The Toeplitz covariate structure provided the best fit for ruminal pH. Probabilities less than or equal to alpha ($P \leq 0.05$) were considered significant, with tendencies acknowledged at *P*-values between 0.05 and 0.10.

Results and Discussion

No dietary treatment effects were observed for DM or OM intake ($P \geq 0.15$; Table 2). However, in a prior feedlot trial, an increase in DMI was observed as bran inclusion increased in the diet up to 30% and a reduction in DMI as the steep inclusion increased in the diet up to 30% when replacing DRC (*1997 Nebraska Beef Cattle Report*, pp 72–74). The effects on DMI were attributed to higher fiber in bran and differences in energy intake between the two ingredients.

Dry matter and OM digestibility for BRAN was least, intermediate for the SEM, and greatest for the CON and STEEP ($P < 0.01$). Neutral detergent fiber intake was greatest for BRAN, intermediate for SEM, and least for CON and STEEP ($P < 0.01$). The difference in NDF intake is related to differences in NDF content of the diets. Neutral detergent fiber digestibility was least for CON and intermediate for BRAN and STEEP ($P = 0.02$) with a tendency for SEM to be greater in NDF digestibility ($P = 0.07$). Starch intake was greatest for the CON because of 40% greater SFC inclusion in the diet. It is important to note that SEM and bran are not devoid of starch and contain 12.41 and 21.07% starch, respectively. No differences in starch digestibility were observed among treatments ($P \geq 0.16$). Apparent energy digestibility was greatest for STEEP and CON (85.6 and 81.6%; $P < 0.01$), although there was no difference between CON and SEM (76.6%). The BRAN treatment had the least apparent energy digestibility (68.0%; $P < 0.01$). Furthermore, cattle fed STEEP consumed the greatest amount of energy per day, with CON being intermediate, and SEM and BRAN being the lowest ($P < 0.01$). Digestible energy (Mcal/lb) was greatest for STEEP, CON, and SEM, which were all greater than the BRAN treatment ($P < 0.01$).

Table 3. Ruminal pH characteristics of steers fed individual Sweet Bran components

	Treatment[1]					
Item	CON	SEM	BRAN	STEEP	SEM	*P*—Value
Minimum	5.56	5.41	5.43	5.51	0.11	0.78
Maximum	7.07	6.90	6.83	6.95	0.10	0.45
Average	6.29	6.22	6.25	6.27	0.06	0.91
Magnitude	1.51	1.49	1.39	1.44	0.15	0.91
Variation[2]	0.33	0.31	0.28	0.30	0.04	0.90

[1]Treatments included CON- control, SEM-solvent extracted germ meal, BRAN- corn bran, STEEP-mixed steep

[2]Standard deviation of daily ruminal pH

Table 4. Rumination characteristics for steers fed individual Sweet Bran components

	Treatment[1]					
Item	CON	SEM	BRAN	STEEP	SEM	*P*—Value
Ruminating, min/day	264.5[b]	229.5[b]	361.5[c]	124.6[a]	25.59	<0.01

[abc]Means in a row with different superscripts are different ($P < 0.05$)

[1]Treatments included CON- control, SEM-solvent extracted germ meal, BRAN- corn bran, STEEP-mixed steep

Physical and digestion characteristics

The physical characteristics of bran, steep, and SEM are also important to consider in addition to the digestion characteristics, although they were not assessed in the current experiment. Steep is a liquid feed, making it difficult to transport, store, and mix in large quantities. Additionally, high inclusions of steep without corn bran and SEM may cause mineral imbalances due to high levels of phosphorus, magnesium, sulfur, sodium, and potassium. As a result, steep is often formulated at low inclusions when fed as an individual ingredient. Steep has a high energy content and is high in protein, especially rumen degradable protein, but low in fiber content. In contrast, corn bran is relatively low in protein, but a highly digestible NDF source. Corn bran is bulky as a single ingredient but is a useful carrier for liquid ingredients such as steep. Corn bran as a carrier allows for higher proportions of steep to be incorporated into the diet due to a reduction in handling, storage, and mixing concerns, in addition to contributing a highly fermentable fiber source. Solvent-extracted germ meal is a medium protein, highly digestible fiber source and is comprised of dry, finely ground particles. This results in SEM settling in the bunk and sorting by cattle. Mixing SEM with corn bran and steep diminishes the separation potential. Overall, the combination of bran, steep, and SEM in Sweet Bran alleviates the handling and sorting concerns when the components are fed individually, resulting in a high protein, highly digestible energy product.

Ruminal pH

No differences were observed for minimum, maximum, average, magnitude of change, or variation of ruminal pH among treatments ($P \geq 0.45$; Table 3). This is inconsistent with previous research that observed lower average pH when steep was included at 30% of diet DM and higher average pH when bran was included at 15% of diet DM when compared to the average pH of a DRC control (*1998 Nebraska Beef Cattle Report*, pp. 69–71). It is unclear why there were no differences observed for ruminal pH considering the inclusion of the bran and steep were higher than in previous experiments.

Rumination

Steers fed the BRAN diet (7.74 lb/d NDF) spent the greatest amount of time ruminating (expressed as minutes per day) with SEM and CON (2.40 and 5.17 lb/d NDF) being intermediate, and STEEP (1.81 kg/d NDF) ruminating the least ($P < 0.01$; Table 4).

Conclusion

Steep and SEM have similar energy densities as the SFC control, while bran is high in NDF and may help control ruminal pH, although this was not observed in the current experiment. These data suggest the physical and nutrient digestibility characteristics of bran, steep, and SEM are complementary when fed in combination and may contribute to the higher energy value of Sweet Bran compared to DRC.

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Evaluate the Effect of Corn Processing, Drying Distillers Grains, Oil Removal from Distillers Grains, and Distillers Inclusion on Cattle Performance

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Summary with Implications

An analysis of over 9,300 head of cattle and 980 pen means was conducted to evaluate the effect of corn processing, drying distillers grains, oil removal from distillers, and distillers inclusion on cattle performance. This analysis looked at both steam-flaked corn and high-moisture corn or dry-rolled corn or a blend of the latter two grains and their effects on performance with and without distillers grains. Additionally, wet, modified, and dried distillers grains were analyzed as both full fat or de-oiled products at various dietary concentrations with each corn type as the primary cereal grain to determine performance responses. There was an overall improvement in performance when steam-flaked corn was utilized regardless of distillers type or level of inclusion. Feeding full fat byproducts resulted in improved feed conversion compared to de-oiled products, but de-oiled products outperformed control diets with no distillers grains. Economic benefits of feeding distillers grains showed that regardless of corn price and the distillers to corn price ratio, feeding between 5–40% distillers was the optimal cost-minimizing solution, regardless of the type of distillers grains.

Introduction

Cattle performance is closely linked to the diet that is offered during the finishing phase and is one of the main drivers of profitability. Cattle performance equations were formulated from an analysis that showed differing response curves related to intake and performance when feeding increasing inclusions of byproducts. These response curves were used to calculate profitability in a tool known as Cattle CODE (*2008 Nebraska Beef Cattle Report*, pp 37–39). This tool accounted for transportation of byproducts, cost of byproducts relative to corn, and performance benefits of each scenario to determine the most economical feeding scenario. This analysis showed the economic benefits of feeding byproducts like dry, modified, and wet distillers grains plus solubles when priced competitively to corn, which was a result of improved feed conversions relative to a control diet with no byproduct. This tool was updated to include more byproduct options in 2011 (*2011 Nebraska Beef Cattle Report*, pp 37–39).

The distillers market has changed considerably over time as it transitioned from low supply and protein valuation to large supply and use as both energy and protein source for cattle and now appears to be changing further with process changes. Most noticeably, distillers grains can now be sold as either full fat (10–12% fat) or de-oiled (6–9% fat). Before 2012, nearly all distillers products were sold as full fat and since then, ethanol plants have marketed de-oiled distillers and corn oil separately. This change has created industry conversation about differences in cattle performance between these two products and if these differences vary by the type of distillers (e.g. wet, modified, dried). The industry also has observed a price increase of distillers grains as more livestock and poultry producers have found uses with a relatively stable yearly ethanol production. This increased price has been coupled with strong seasonal patterns as the supply of distillers is the largest in the summer coupled with low demand from cattle feeders due to fewer cattle on feed. Seasonal dynamics in the fall are reversed, which results in increased demand from cattle feeders coupled with a lower supply of distillers from ethanol plants.

Another change that has occurred in the last 10 years in Nebraska is an increase in feedyards that steam-flake corn. Traditionally most feedyards in the Midwest fed dry-rolled corn (DRC), high-moisture corn (HMC), or a blend of the two grains. However, some yards are now utilizing steam-flaked corn (SFC) as their primary source of grain. This transition in corn processing has occurred likely due to increased performance benefits coupled with the volatile distillers' prices. Therefore, the objective of this analysis was to summarize all available trial data, calculate new cattle performance response functions, and then use these to calculate economic tradeoffs based on the different distillers products at different levels of inclusion when fed in either a SFC or HMC:DRC based finishing diets.

Procedure

This dataset included over 9,300 head of cattle and a total of 42 studies that were conducted at the University of Nebraska-Lincoln. Pen studies that were analyzed had 5–20 animals per pen. All trials were conducted between 1992 and 2020 and encompassed over 980 pen means. Cattle were sorted into calf-feds (< 775 lb initial weight) or yearlings (> 775 lb initial weight) to help differentiate performance differences between these two types of cattle.

Corn type was separated into two categories which were: SFC or HMC:DRC. The first category included only cattle that were fed exclusively SFC as the grain in the finishing diet, whereas the HMC:DRC included cattle fed either HMC, DRC, or any blend of the HMC and DRC as the concentrate in the finishing diet. Over 85% of the pens were fed a HMC:DRC based finishing diet (Table 1). Distillers types including dry (DDGS), modified (MDGS), and wet (WDGS) distillers grains plus solubles were also evaluated. Each distillers type was further separated into either full fat (FF; 10–12% fat) or de-oiled (DO; 6–9% fat) byproducts. A total of 410 pen observations were fed WDGS, which represented the largest proportion of cattle fed a

Table 1. Pen observations by type of distillers grains and corn.

	Corn Type by Cattle Weight Class				Totals		
	< 775 lb		> 775 lb		Oil Type		Distillers Grains
	DRC:HMC[1]	SFC[2]	DRC:HMC	SFC	DRC:HMC	SFC	DRC:HMC + SFC
DDGS[3]							
BOTH[4]	34	6	40	0	**74**	**6**	**80**
MDGS[5]							
DO[6]	9	24	16	0	**25**	**24**	**49**
FF[7]	38	0	82	0	**120**	**0**	**120**
					175	**24**	**169**
WDGS[8]							
DO	18	24	43	10	**61**	**34**	**95**
FF	150	23	126	16	**276**	**39**	**315**
					337	**73**	**410**
Control[9]	123	27	155	18			

[1]DRC:HMC—diets with dry-rolled corn, high-moisture corn, or a blend of the two grains as the concentrate

[2]SFC—diets with steam-flaked corn as the concentrate

[3]DDGS—dry-distillers grains plus solubles

[4]BOTH—includes both de-oiled and full-fat studies

[5]MDGS—modified distillers grains plus solubles

[6]DO—de-oiled distillers grains (6–9% fat)

[7]FF—full fat distillers grains (10–12% fat)

[8]WDGS—wet distillers grains plus solubles

[9]Control—diets containing no distillers grains

byproduct in this data set. Each byproduct included observations between 0% and 40% inclusion on a DM basis. Although some studies included inclusions of more than 40%, the number of observations and the industry implications did not warrant accurate modeling above 40% inclusion. These studies did not contain any observations for FF MDGS fed in SFC based finishing diets, as a result, the performance could not be modeled. Additionally, only 6 pen means were available to model DDGS fed in SFC based finishing diets, which should be considered while interpreting the results.

Cattle performance, which included average daily gain (ADG), feed conversion (F:G), and dry matter intake (DMI), response functions were calculated for each distillers using a combination of distillers and corn type attributes. The final model included the fixed effects of corn processing type (TYPE: SFC, HMC/DRC, NONE), linear and quadratic effects of byproduct level (LEVEL), linear cattle placement weight (IW), fixed effects of byproduct oil (OIL: DO, FF), and random effects for the trial (TRIAL), experimental block (BLOCK) nested within the trial, and residual error. Non-significant interactions and quadratic terms ($P > 0.05$) were dropped to produce the final model for each distillers. Normal distributions were assumed for all traits measured. Significance was determined at $P < 0.05$. All analyses were performed using the lme4 package in R.

A few modifications were made to the cattle performance response functions for DDGS due to a lack of data. Specifically, the FF DDGS fed with SFC was not able to be estimated as there were no pen trials. Thus, DDGS cattle performance response functions by oil type were combined into one equation (e.g. DDGS-BOTH). A total of 6 byproduct options are available with each corn type: FF WDGS, DO WDGS, FF MDGS, DO MDGS, FF DDGS, and DO DDGS.

Using the estimated cattle performance response functions by type of distillers grain and corn used in the cattle finishing diet, an economic analysis was conducted to determine which type and level of inclusion of distillers minimized the total cost to finish a steer ($/head). Results were estimated at various levels of corn prices (e.g. $4.00/bu, $6.00/bu, and $8.00/bu) and distillers to corn price ratios (e.g. 80%, 100%, and 120%). When comparing DDGS, MDGS, or WDGS, products were priced equal on a DM basis to allow for economic comparisons based on performance differences. No additional cost associated with trucking distillers was accounted for in this model.

A base diet was modeled which included corn, distillers grains (if any), grass hay, and a supplement. Corn was calculated assuming a 56-pound bushel at 85% DM. Additionally, corn processing cost was added when SFC was utilized to reflect $9.00/DM ton for the cost of flaking the corn. Each diet scenario consisted of a base diet with 7% DM grass hay and 5% DM supplement inclusion. The price of grass hay was $100.00/DM ton and the price of the supplement was set at $300.00/DM ton.

The total cost to finish one steer entering the feedlot at 775 lbs and being shipped at 1350 lbs was calculated for each ration combination. Equations were used to predict ADG of each diet, which determined days on feed (DOF). Using DOF, the total tonnage of feed required was calculated based on DOF x DMI = total feed. Additionally, yardage costs were calculated based on $0.60/hd/d. The total cost associated with finishing one steer reflected both feed

Table 2. Pen performance summary by type of distillers grains and corn.

By Product	Corn Type	Trials (N)	DGS Pens (N)	Control Pens (N)	Avg. % Distillers	Trial Cattle Performance (i.e. Distillers in Diet)				Control Cattle Performance (i.e. No Distillers in Diet)			
						In weight	ADG[1]	F:G[2]	DMI[3]	In weight	ADG	F:G	DMI
DDGS[4]- DO[5]													
	DRC:HMC[6]	2	12	12	35	628	3.74	5.79	21.50	628	3.46	6.04	20.80
	SFC[7]	1	6	6	30	635	3.44	5.82	20.00	635	3.24	5.68	18.40
DDGS- FF[8]													
	DRC:HMC	7	62	41	33	837	4.01	6.84	27.40	821	3.63	7.02	25.50
	SFC	-	-	-	-	-	-	-	-	-	-	-	-
MDGS[9]-DO													
	DRC:HMC	3	25	19	27	804	3.61	6.43	23.10	807	3.32	6.74	22.30
	SFC	1	24	8	20	636	4.06	5.52	22.30	637	3.75	5.86	21.90
MDGS-FF													
	DRC:HMC	8	120	63	28	836	3.94	6.39	25.10	841	3.63	6.74	24.40
	SFC	-	-	-	-	-	-	-	-	-	-	-	-
WDGS[10]-DO													
	DRC:HMC	6	61	42	29	805	3.97	6.41	25.40	816	3.74	6.85	25.50
	SFC	2	34	13	22	705	4.01	5.85	23.40	727	3.72	6.39	23.70
WDGS-FF													
	DRC:HMC	28	276	169	30	764	3.94	6.12	23.90	764	3.62	6.67	24.00
	SFC	4	39	31	32	763	4.00	5.81	22.80	781	3.84	6.18	23.10

[1]ADG—average daily gain

[2]F:G—feed:gain

[3]DMI—dry matter intake

[4]DDGS—dry distillers grains plus solubles

[5]DO—de-oiled distillers grains (6–9% fat)

[6]DRC:HMC—diets with dry-rolled corn, high-moisture corn, or a blend of the two grains as the concentrate

[7]SFC—diets with steam-flaked corn as the concentrate

[8]FF—full fat distillers grains (10–12% fat)

[9]MDGS—modified distillers grains plus solubles

[10]WDGS—wet distillers grains plus solubles

and yardage costs, which were used to determine the optimum inclusion of distillers.

Results

The results of this analysis showed the performance benefits of feeding SFC relative to HMC:DRC based finishing diets. Cattle fed SFC had lower DMI and similar ADG compared to cattle fed HMC:DRC, which resulted in a 0.6–0.7 lb improvement in feed conversion. This trend was evident in both control-fed cattle and cattle where distillers were included in the diet. Overall, these data suggest that feeding SFC would reduce the total tonnage of feed needed to achieve similar gains when fed equal days on feed.

Feeding distillers grains resulted in increased DMI and increased ADG on average, regardless of corn type. (Table 2). This intake and gain response resulted in a 0.3 unit improvement in feed conversion and suggests that including distillers grains improves the efficiency of cattle compared to cattle fed without distillers. This response was largely influenced by the feed conversion improvement when WDGS was included in the diet. Cattle fed DO WDGS and FF WDGS both had similar DMI as the control fed cattle but had 0.20 lbs/d improvements in ADG. The oil content of the distillers products showed cattle fed FF products had similar DMI but improved ADG and 0.13 lb improvement in feed conversion compared to cattle fed DO products. In HMC:DRC based diets, FF WDGS improved feed conversion by an average of 4.74% compared to DO WDGS. However, when comparing FF MDGS to DO MDGS when fed in HMC:DRC based diets, less than a 1% difference in feed conversion was observed. When comparing MDGS to WDGS, regardless of oil level, feeding WDGS improved feed conversion by 2.31% suggesting wetter products will improve performance. Although the data suggests that feeding DDGS will improve feed conversion compared to either MDGS or WDGS, this is likely a reflection of the type of cattle being fed in the few studies that contain DDGS. Studies that evaluated DDGS performance were conducted on primarily calf-fed animals, which tend to have lower DMI and ADG, but improved F:G compared to yearling cattle. This increased proportion of calf-fed observa-

Table 3. Optimum inclusion of distillers based on performance and pricing relative to each corn type.

By Product	Corn Type	Optimal Inclusion Level Based on Animal Performance:			Optimal Inclusion Level Based on Pricing:								
					Distillers Price is 80% of Corn Price with:			Distillers Price is 100% of Corn Price with:			Distillers Price is 120% of Corn Price with:		
		ADG[1]	F:G[2]	DMI[3]	$4 Corn	$6 Corn	$8 Corn	$4 Corn	$6 Corn	$8 Corn	$4 Corn	$6 Corn	$8 Corn
DDGS[4]-DO[5]													
	DRC:HMC[6]	36	40	37	38	38	38	33	33	33	19	9	9
	SFC[7]	36	40	37	40	40	40	31	31	31	16	12	12
DDGS-FF[8]													
	DRC:HMC	36	40	37	38	38	38	33	33	33	19	9	9
	SFC	36	40	37	40	40	40	31	31	31	16	12	12
MDGS[9]-DO													
	DRC:HMC	28	40	24	39	39	39	36	36	36	12	12	12
	SFC	28	40	24	40	40	40	36	40	40	11	7	1
MDGS-FF													
	DRC:HMC	28	40	24	39	39	39	35	39	39	17	7	7
	SFC	28	40	24	40	40	40	36	40	40	11	7	1
WDGS[10]-DO													
	DRC:HMC	29	40	19	40	40	40	35	35	35	22	22	22
	SFC	29	40	19	40	40	40	36	36	36	27	27	27
WDGS-FF													
	DRC:HMC	29	40	19	40	40	40	34	34	34	24	24	24
	SFC	29	40	19	40	40	40	35	35	35	23	23	23

[1]ADG—average daily gain

[2]F:G—feed:gain

[3]DMI—dry matter intake

[4]DDGS—dry distillers grains plus solubles

[5]DO—de-oiled distillers grains (6–9% fat)

[6]DRC:HMC—diets with dry-rolled corn, high-moisture corn, or a blend of the two grains as the concentrate

[7]SFC—diets with steam-flaked corn as the concentrate

[8]FF—full fat distillers grains (10–12% fat)

[9]MDGS—modified distillers grains plus solubles

[10]WDGS—wet distillers grains plus solubles

tions fed DDGS resulted in improved feed conversion compared to MDGS and WDGS fed cattle.

When distillers are priced at 80% the value of corn, there is a reduction in the total cost as the inclusion of distillers approaches 40%, regardless of distillers type (Table 3). In HMC:DRC diets, as distillers DM decreases from DDGS to WDGS, the cost benefit increases in favor of the wetter products. As the distillers' price increases to 120% the value of corn, the optimum inclusion decreases, but the cost is still reduced by including distillers between 7–24% depending on the diet combination. For example, in HMC:DRC based diets, the optimum inclusion of FF WDGS is still 24% DM even though it is priced 20% higher than corn. This reflects the additional performance that FF WDGS yields when fed in these diets. In SFC based diets, the economic average optimum of FF WDGS and DO WDGS is 25% DM inclusion.

Conclusion

Overall this analysis showed the performance benefits of feeding SFC relative to HMC:DRC, which lowered DMI and feed conversion and made it economically viable even with the additional processing costs. Feeding distillers grains resulted in improved performance and improved feed conversion, which was economically beneficial, especially when distillers were priced at or below corn price. The benefits of feeding WDGS are slightly larger in HMC:DRC based diets, which resulted in higher optimum inclusions even when priced at 120% the value of corn. However, WDGS should still be included in SFC based diets even when priced higher than corn. The fat level did show that FF products have slightly more performance benefits than DO products but feeding DO products still improve performance and economics. Additional research with distillers grains in SFC based diets is needed. The benefits of feeding distillers, especially wetter products, are evident and economically favorable in both corn types up to 120% the value of corn.

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Impact of Constant Inclusion or Decreasing Inclusion of Distillers Grains with High-quality or Low-quality Roughage on Finishing Cattle Performance

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Summary with implications

A finishing trial was conducted to evaluate high-quality or low-quality roughage inclusion in diets containing three concentrations of modified distillers grains plus solubles on finishing cattle performance. In a randomized block design, steers were fed according to a 2x3 factorial arrangement with two roughage sources (6% corn stalks versus 12% corn silage) in three diets containing 0, 15, or decreasing inclusion of distillers (30, 15, then 0% across the feeding period). No interactions were observed between distillers inclusion and roughage source except for intake. Steers fed corn silage consumed less, gained the same, and had slightly better feed conversions. Steers fed 0% distillers grains had lower average daily gain, hot carcass weight, less 12th rib fat, and poorer feed conversion compared with those fed 15% distillers grains. Steers fed 15% distillers continuously had greater intake and gain compared to steers fed decreasing inclusion of distillers from 30% to 0% (average inclusion of 15%), but feed conversion was not impacted.

Introduction

Roughage is included in feedlot diets to improve rumen health and to increase dry matter intake and average daily gain. Previous research suggested that roughage sources can be exchanged if forage neutral detergent fiber (NDF) is maintained, without affecting cattle performance. Results from other experiments also suggested that roughage concentrations may vary without having a negative impact on average daily gain and cattle efficiency when fed with corn gluten feed, but not with distillers grains plus solubles. When fed at 30% distillers grains in the diet, feeding low-quality forages like cornstalks yielded the same performance as feeding higher quality forage (alfalfa hay or corn silage). Under current economic conditions, dietary inclusion of distillers grains average is approximately 15%; thus, a question asked is what is the impact of feeding cornstalks instead of high-quality roughages when distillers supply is reduced?

The objective of this study was to evaluate the effects of feeding high-quality or low-quality roughage in diets containing 0% or 15% distillers or those where distillers inclusion is phased from 30% to 0% on finishing cattle performance and carcass quality.

Table 1. Dietary treatment composition for cattle fed 0% MDGS, 15% MDGS and 30–0 (15)% MDGS with either corn silage or corn stalks as roughage source.

	Treatments[1]					
	Corn silage			Corn stalks		
Ingredient	0	15	30–0 (15)	0	15	30–0 (15)
Dry-rolled corn	41.5	34	Variable	44.5	37	Variable
High-moisture corn	41.5	34	Variable	44.5	37	Variable
Distillers grains	0	15	30-15-0	0	15	30-15-0
Corn silage	12	12	12	-	-	-
Corn stalks	-	-	-	6	6	6
Supplement[2]	5	5	5	5	5	5
Urea	1.2	0	variable	1.2	0.5	Variable

[1] Treatments included 0% MDGS, 15% MDGS, or diets with 30% MDGS fed for the first 1/3 of the feeding period, 15% MDGS fed for the middle 1/3 of the feeding period, and then stepped to 0% MDGS inclusion the last 1/3 of the feeding period.

[2] Supplements provided minerals, vitamins, 30 g/ton monensin (Rumensin, Elanco Animal Health) and to provide 90 mg/steer daily of tylosin (Tylan, Elanco Animal Health)

Procedure

An experiment was conducted at the Eastern Nebraska Research, Extension and Education Center. Crossbred steers (n = 480 steers, initial BW 644 ± 43 lb) were utilized in a randomized block experiment with a 2 ×3 factorial arrangement of treatments, for which 48 pens were used, with 8 pens per treatment and 10 steers per pen. Dietary treatments (Table 1) included two roughage sources (6% corn stalks versus 12% corn silage DM basis) in three diets containing 0, 15%, or decreasing inclusion of distillers (30, 15, then 0% across the feeding period).

Steers were limit-fed at 2% BW for five days to equalize gut fill and were weighed on two consecutive days at the beginning of the trial to determine initial body weight. Steers were assigned randomly to pen and blocked by initial body weight. Steers were implanted with Revalor-IS on day 1 and reimplanted with Revalor-200 on day 78 of the feeding period. Steers were fed ractopamine (Optaflexx, Elanco Animal Health) the last 28 d at 300 mg/steer daily with 2 days removed prior to slaughter. After 196 days on feed, cattle were harvested at a commercial abattoir where hot carcass weight (HCW) and incidence of liver abscesses were recorded. After a 48-hour chill, marbling score, longissimus muscle (LM) area and back fat thickness were recorded, and yield grade was calculated.

Data were analyzed using the Mixed procedure of SAS. Pen was set as the experimental unit and treatment was a fixed effect. Interactions between roughage and distillers treatment were tested. If not

Table 2. Main effects of modified distillers grains plus solubles (MDGS) inclusion on feedlot cattle performance and carcass characteristics

	Distillers grain inclusion[1]					
	0 DGS	15 DGS	30-15-0	SEM	F-test	15 vs 30-15-0
Initial BW, lb	646	645	647	0.8	0.47	0.23
DMI, lb/d	22.2[c]	24.4[a]	23.2[b]	0.17	<0.01	<0.01
ADG, lb	3.73[c]	4.18[a]	4.06[b]	0.045	<0.01	< 0.01
F:G[2]	6.20[a]	5.95[b]	5.85[b]	-	<0.01	0.25
HCW, lb	874[b]	930[a]	916[a]	5.6	<0.01	0.07
LM area[3], in	14.3	14.4	14.5	0.12	0.53	0.99
Fat, in	0.55[b]	0.68[a]	0.65[a]	0.023	<0.01	0.32
Marbling[4]	538[b]	562[a]	544[b]	7.1	0.03	0.06

[a-c] Within a row, means without a common superscript differ ($P < 0.06$)

[1] Treatments included 0% MDGS, 15% MDGS, or diets with 30% MDGS fed for the first 1/3 of the feeding period, 15% MDGS fed for the middle 1/3 of the feeding period, and then stepped to 0% MDGS inclusion the last 1/3 of the feeding period.

[2] Analyzed as G:F, the reciprocal of F:G

[3] LM area = longissimus muscle (ribeye) area

[4] Marbling score 400 = Small00, 500 = Modest00, 600 = Moderate00

Table 3. Main effects of roughage source on feedlot cattle performance and carcass characteristics

	Roughage source			
	Silage	Stalks	SEM	*P*-value
Initial BW, lb	646	646	0.7	0.76
DMI, lb/d	23.1	23.4	0.14	0.12
ADG, lb	4.03	3.96	0.038	0.19
F:G[1]	5.89	6.10	-	<0.01
HCW, lb	911	902	4.7	0.18
LM area[2], in	14.3	14.5	0.10	0.13
Fat, in	0.64	0.62	0.019	0.44
Marbling[3]	554	542	5.9	0.11

[1] Analyzed as G:F, the reciprocal of F:G

[2] LM area = longissimus muscle (ribeye) area

[3] Marbling score 400 = Small00, 500 = Modest00, 600 = Moderate00

significant, then main effects were summarized for either effect of distillers treatment or roughage source. If significant, then simple effect of roughage source within distillers diet were evaluated.

Results

There was an interaction ($P = 0.04$) between roughage source and MDGS inclusion for dry matter intake (DMI). Cattle fed diets with 0% distillers inclusion had the lowest DMI for both roughage sources, which increased by about 2 lb per day over the feeding period when 15% distillers was included. The reason for the interaction is that when distillers decreased from 30% to 0% over the feeding period, intake response was slightly different depending on which roughage source was used. Cattle fed silage had intakes of 22.3, 24.2, and 22.7 lb/d for 0, 15, and 30–0%, respectively. For cattle fed stalks as the roughage source, intakes were 22.0, 24.5, and 23.6 lb/d for 0, 15, 30–0%, respectively. No other significant interactions were observed, so main effects are presented.

Cattle fed the diet with 0% MDGS inclusion (Table 2) had reduced ($P < 0.05$) HCW, ADG, and 12th rib fat, and greater F:G compared to cattle fed diets where MDGS was 15% inclusion continuously or when MDGS decreased from 30% to 0%. Even though the average inclusion of MDGS was 15% for the treatment where MDGS was decreased from 30% to 0%, performance differed from that of cattle fed 15% distillers continuously. Cattle fed decreasing inclusions of MDGS (30–0%) had lower ($P < 0.01$) DMI, ADG and tended ($P = 0.07$) to have lighter HCW. Feed conversion was not ($P = 0.25$) affected when distillers was fed at 15% continuously or when decreased from 30% to 0% inclusion. Marbling score was impacted by distillers inclusion ($P = 0.03$), where cattle fed 15% MDGS had greater ($P = 0.01$) marbling score than 0% inclusion and tended ($P = 0.06$) to be greater than cattle fed 30–0% MDGS. Even though there are differences in marbling score across treatments, all three treatments were within the choice grade (Table 2) and reflects ADG differences across treatments.

Cattle fed silage (Table 3) gained the same, and had better feed conversion ($P < 0.01$) compared to steers fed stalks. Based on numerically lower HCW, ADG, fatness, and marbling, these data suggest that feeding 6% corn stalks did not produce similar performance as feeding 12% corn silage. These data suggest that feeding 15% distillers was not enough to offset lower quality roughage (stalks) compared to silage as roughage which contradicts previous studies when 30% distillers were fed.

Conclusion

Cattle fed no distillers grains in feedlot finishing diets had poorer feedlot performance. Lowering distillers inclusion over the feeding period negatively affected intake and gain. With 0% to 15% distillers inclusion, feeding corn silage as a roughage source improved conversion compared to stalks.

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Impact of Removing 20% Distillers Grains after One-third or Two-thirds of the Feeding Period on Performance of Finishing Yearlings

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Summary with Implications

A finishing study evaluated the effect of removing modified distillers grains plus solubles after one-third or two-thirds of the feeding period on performance and carcass characteristics of yearling steers. Treatment diets included 20% modified distillers for the entire feeding period; 20% modified distillers for two-thirds of the feeding period and then 0%; and 20% modified distillers for one-third of the feeding period, then 0%. Removing modified distillers from the diet decreased average daily gain, final body weight and dry matter intake and tended to increase feed conversion. Cattle fed 20% modified distillers throughout the entire feeding period had greatest hot carcass weight and longissimus muscle area. There was no difference in marbling score, backfat and percent of abscessed livers. Removal of modified distillers negatively impacted performance and impact depended on length of the feeding period without distillers inclusion. These data suggest running out of distillers during the feeding period will have negative consequences on gain and conversions.

Introduction

Disruption in distillers grains plus solubles supply may force producers to lower inclusion while cattle are on feed. It is not clear what impact complete removal of distillers may have on performance and carcass characteristics.

There is no previous research that evaluates distillers grains removal. Some experiments have evaluated the effect of phase feeding to meet cattle's protein requirements throughout the feeding period. These experiments suggest that dry matter intake may decrease when using phase-feeding regimens, although average daily gain has not been reported to decrease. More research is needed to evaluate the impact of removing distillers grains from the finishing diet, not just lowering distillers inclusion.

The objective of this study was to evaluate the impact of modified distillers grains plus solubles (MDGS) removal from 20% to 0% on day 43 and day 79 on yearling finishing performance compared to feeding 20% in the entire feeding period.

Table 1. Dietary treatment composition for cattle fed 20% MDGS and then stepped down to 0% MDGS for those treatments (% of the diet DM)

	20% MDGS	Transition	0% MDGS
High-moisture corn	36	42	48
Dry-rolled corn	24	28	32
Corn silage	15	15	15
Modified distillers grains[1]	20	10	0
Supplement[2,3]	5	5	5

[1]MDGS was replaced with HMC-DRC blend when removed

[2]Urea was added to the supplement at 1.4% of the diet DM when MDGS was removed

[3]Supplement provided 90 mg/steer daily of Tylan (Elanco Animal Health) and formulated for 30 g/ton of DM for Rumensin (Elanco Animal Health)

Procedure

An experiment was conducted at the Eastern Nebraska Research, Extension and Education Center to evaluate the impact of MDGS removal from 20% of diet dry matter to 0% on day 43 and day 79 on yearling finishing performance and carcass characteristics compared to feeding 20% for the entire feeding period. Crossbred yearling steers (n = 210; initial BW 947 ± 49 lb) were used in a randomized block design with three body weight (BW) blocks. Steers were stratified by weight and assigned randomly to pen. Cattle were limit-fed for five days to equalize gut fill and weighed on two consecutive days at the beginning of the experiment to establish initial BW. Cattle were implanted with Revalor-200 (Merck Animal Health) on day -1. Treatments included feeding 20% MDGS (DM basis) during the entire feeding period (124 d); 20% MDGS until day 79 and then 0% MDGS until the end of the feeding period; or 20% MDGS until day 43 and then 0% MDGS until the end of the feeding period. A total of 21 pens (10 steers/pen) were used with 7 pens/treatment. Cattle were fed a 60:40 blend of high-moisture and dry-rolled corn, with 15% corn silage, 20% MDGS and 5% supplement (Table 1). Distillers were replaced with the corn blend and urea (1.4% of the diet DM) when removed. Cattle were stepped down to 10% MDGS for 4 days before the complete removal of MDGS. At the end of the feeding period, cattle were harvested at a commercial abattoir. Hot carcass weight and liver abscesses were recorded at harvest and marbling score, longissimus muscle area and yield grade, were recorded after a 48-hour chill.

Data were analyzed using the Mixed procedure of SAS. Pen was the experimental unit and treatment was a fixed effect.

Results

Cattle with MDGS removed on either d 79 or d 43 had lower ($P < 0.05$) final BW, DMI, and ADG (Table 2). Cattle with

Table 2. Carcass adjusted performance of cattle fed 20% MDGS during 124 d, 79 d, or 43 d of the 124-day feeding period.

	124 d	79 d	43 d	SEM	F-test	Lin	Quad
Initial BW, lb	963	962	962	0.7	0.29	0.16	0.48
Final BW[1], lb	1596[a]	1557[b]	1528[c]	11.7	< 0.01	<0.01	0.89
DMI, lb/d	31.9[a]	30.8[b]	29.9[c]	0.30	< 0.01	<0.01	0.99
ADG, lb	5.11[a]	4.79[b]	4.57[b]	0.093	< 0.01	<0.01	0.90
F:G[2]	6.49	6.61	6.73	-	0.36	0.025	0.78
HCW, lb	1006[a]	981[b]	963[b]	7.3	< 0.01	<0.01	0.89
LM area[3], in	14.3[a]	14.0[b]	13.9[b]	0.12	0.02	<0.01	0.49
Fat, in	0.72	0.67	0.68	0.028	0.39	0.25	0.46
Marbling[4]	607	604	578	15.7	0.35	0.20	0.52
Liver abscess, %	38	41	46	-	0.59		
A+ abscess, %	26	14	21	-	0.85		

[ac]Within a row, means without a common superscript differ ($P < 0.05$)

[1] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage

[2] Analyzed as G:F, the reciprocal of F:G

[3] LM area = longissimus muscle (ribeye) area

[4] Marbling score 400 = Small00, 500 = Modest00, 600 = Moderate00.

MDGS removed on d 43 had 4% poorer Feed:Gain ($P < 0.05$) than cattle fed 20% MDGS throughout the entire feeding period. Cattle fed 20% MDGS throughout the entire feeding period had the greatest ($P < 0.05$) HCW and LM area. There were no differences ($P \geq 0.35$) in backfat and marbling scores among treatments. In addition, no differences ($P = 0.59$) were observed in percent of abscessed livers, although 38% of steers fed 20% MDGS continuously had liver abscesses compared with 46% for steers with MDGS removed on d 43. Based on the results of this study, removing MDGS from finishing diets on either day 43 or day 79 of the feeding period had a negative impact on cattle performance compared with feeding 20% MDGS continuously throughout the entire finishing period.

Conclusion

Removing MDGS from finishing diets has a negative impact on performance and carcass characteristics compared with feeding 20% MDGS continuously throughout the entire finishing period. These changes in performance may relate to MDGS having greater energy than corn/urea used to replace it when removed. Due to pen number limitations, a corn control was not included to compare energy values like previous research.

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Supplemental Lysine in Finishing Cattle Diets

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Summary with Implications

The objective of this experiment was to evaluate the effects of increasing lysine supply in finishing beef cattle diets. Crossbreed steers (n=120, BW= 577± 2 lb) were individually fed using a Calan Gate system for 195 days. Animals received a common finishing diet (63% corn, 15% corn silage and 15% distillers grains) with 0, 1, 2, 3, 4, 5, 6, or 7 g per day of supplemental rumen bypass lysine. High levels of lysine (5 or more g per day) in the diet decreased dry matter intake, carcass adjusted average daily gain, and carcass adjusted body weight with no impact on carcass adjusted feed efficiency. Hot carcass weight decreased as supplemental lysine increased in the diet with no impact on other carcass performance parameters. In conclusion, there were no improvements in performance as supplemental lysine increased in finishing beef cattle diets.

Introduction

In Nebraska, corn and corn byproducts are the primary ingredients in most finishing cattle diets. Lysine has been found to be the first limiting amino acid in corn-based beef cattle diets. To meet lysine requirements, crude protein is often increased in beef cattle diets; however, increasing crude protein can lead to decreased efficiency in nitrogen utilization and increased nitrogen excretion in urine. Rumen-protected lysine sources have been used to help meet lysine requirements and may improve performance and ADG of cattle when lysine is limiting growth.

The objective of this experiment was to evaluate if increasing rumen protected lysine supply in finishing beef cattle diets would improve cattle performance.

Procedure

This experiment utilized 120 crossbred beef steers (577 ± 2 lbs) at the Eastern Nebraska Research, Extension, and Education Center (ENREEC) near Mead, NE. Steers were individually fed using the Calan Gate System (American Calan Inc., Northwood, New Hampshire). Steers were fed a base diet of 15.0% modified distillers grains plus solubles, 15.0% corn silage, 39.6% high moisture corn, 23.4% dry rolled corn, 4.0% supplement, and 3.0% Smartamine ML topdress consisting of dry rolled corn and Smartamine ML. Smartamine ML (Adisseo USA, Inc., Alpharetta, Georgia) is a rumen-protected source of lysine that is 80% bioavailable for the animal. This product consists of 55% hydrochloride lysine, 15% methionine, and 30% inert products. The Smartamine ML topdress was fed to provide 0, 1, 2, 3, 4, 5, 6, or 7 grams of post-rumen available lysine daily, which also provided 0. 0.3, 0.7, 1.0, 1.4, 1.7, 2.0, and 2.4 grams per day of methionine. The amount of Smartamine ML provided to each steer was consistent throughout the experiment and the amount of dry rolled corn in the top dress varied based on intake to maintain the top dress at 3% of the diet. The Smartamine ML topdress was mixed weekly in a small batch mixer.

Initial BW was determined by 3 days of individual weighing following a 5-day period of limit feeding a 50% alfalfa, 50% Sweet Bran (Cargill Corn Milling, Blair, NE) diet at 2% BW to equalize gut fill. On days 63 and 64, two consecutive day body weights were taken in the morning prior to feeding. On day 162, a one-day weight was taken.

Cattle were implanted with Revalor XS (Merck Animal Health, Summit, NJ) on day 1 and reimplanted with Revalor-200 (Merck Animal Health) on day 91. Optaflexx (Elanco Animal Health, Greenfield, IN) was fed from days 163 to 195 at a rate of 300 mg/steer daily. Cattle were on feed for 195 days. Animals were slaughtered at a commercial abattoir (Greater Omaha Packing Plant, Omaha, NE). During harvest, hot carcass weight (HCW) was recorded, and carcass adjusted final BW was calculated based on a common 63% dress. Carcass characteristics including marbling, 12th rib fat thickness, yield grade, and *Longissimus* muscle (LM) area were collected after a 48-hour chill.

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) as a completely randomized design with steer (n= 15) as the experimental unit and treatment as the fixed effect. Orthogonal contrasts were used to explore the linear and quadratic responses. Contrasts were also used to compare the control and 1, 2, and 3 g/d treatment groups, which were deemed to be the most biologically and economically relevant treatments.

Table 1. Diet composition for steers fed varying amounts of rumen-protected lysine

Ingredient	% DM
High moisture corn	39.60
Dry rolled corn	23.40
Modified Distillers Grains plus Solubles	15.00
Corn Silage	15.00
Supplement[1]	4.00
Smartamine ML topdress[2]	3.00
Smartamine ML	0–7 g/d available lysine

[1] Supplement provided 1.66% limestone, 0.30% salt, 0.10% tallow, 0.05% trace mineral premix, 0.015% Vitamin ADE, 0.50% Urea (to meet RDP requirement), Tylan (Elanco Animal Health) targeted at 8.8 g/ton of DM, Rumensin (Elanco Animal Health) targeted at 30 g/ton of DM, and Optaflexx (Elanco Animal Health) for the last 28 d targeted at 300 mg/day, with a fine ground corn carrier.

[2]Smartamine ML topdress included dry rolled corn and Smartamine ML with dry rolled corn replacing Smartamine ML as amount of lysine decreased in the diet. Smartamine ML amount was consistent throughout the trial with dry rolled corn amount varying based on intake.

Table 2. Effect of rumen-protected lysine on cattle performance

	Treatment									*P*-Values[1]				
	0	1	2	3	4	5	6	7	SEM	Linear	Quadratic	0 vs 1 g/d	0 vs 2 g/d	0 vs 3 g/d
Steers, n	15	14	15	15	14	15	15	15						
Overall Performance[2]														
Initial BW, lb	577	574	577	578	580	577	578	577	6.19	0.73	0.80	0.80	0.97	0.89
Final BW, lb	1298	1304	1282	1271	1292	1272	1244	1269	22.26	0.07	0.87	0.84	0.59	0.38
DMI, lb/d	20.7	19.9	19.6	19.2	20.2	19.3	19.3	19.3	0.49	0.04	0.44	0.26	0.12	0.03
ADG, lb	3.70	3.74	3.62	3.56	3.65	3.56	3.41	3.55	0.11	0.04	0.81	0.78	0.57	0.33
Feed: Gain[3]	5.56	5.32	5.43	5.41	5.56	5.38	5.62	5.43	—	0.72	0.67	0.23	0.50	0.43
Day 64 Performance[4]														
DMI, lb/d	17.3	16.6	17.0	16.6	16.8	16.5	17.1	16.5	0.46	0.48	0.62	0.26	0.68	0.25
ADG, lb	3.49	3.47	3.48	3.24	3.35	3.28	3.25	3.22	0.14	0.05	0.81	0.92	0.95	0.20
Feed: Gain[3]	4.97	4.78	4.87	5.10	5.05	5.02	5.23	5.12	—	0.08	0.94	0.40	0.68	0.55
Optaflexx Period Performance[5]														
DMI, lb/d	21.5	20.2	19.0	19.9	20.5	19.7	18.5	18.9	0.70	0.01	0.74	0.21	0.01	0.10
ADG, lb	3.21	3.11	2.86	3.51	3.11	3.12	2.73	3.26	0.38	0.81	0.99	0.86	0.51	0.56
Feed: Gain[3]	6.58	6.45	6.80	5.65	6.62	6.29	6.85	5.88	—	0.69	0.99	0.90	0.86	0.34

[1]Orthogonal contrasts were used to explore the linear and quadratic responses, and contrasts were also used to compare the control and 1, 2, and 3 g/d treatment groups.

[2]Indicates performance from day 1 to day 195 (conclusion of experiment) using carcass adjusted final body weight and 63% dress.

[3]Analyzed as Gain: Feed, the reciprocal of Feed: Gain

[4] Indicates performance from day 1 to day 64 of experiment

[5] Indicates performance from day 163 to day 195 (conclusion of experiment) while Optaflexx was being fed

Table 3. Effect of rumen-protected lysine on carcass characteristics

	Treatment									*P*-Values[1]				
	0	1	2	3	4	5	6	7	SEM	Linear	Quadratic	0 vs 1 g/d	0 vs 2 g/d	0 vs 3 g/d
Steers	15	14	15	15	14	15	15	15						
HCW, lb	818	822	808	801	814	801	784	800	14.0	0.07	0.87	0.84	0.59	0.38
LM Area, in^2	14.2	14.2	14.2	13.9	14.4	14.5	14.3	14.2	0.34	0.62	0.99	0.91	0.89	0.50
12th Rib Fat^2, in	0.41	0.42	0.45	0.42	0.44	0.37	0.42	0.36	0.03	0.20	0.18	0.81	0.33	0.76
Marbling Score[3]	456	463	470	421	471	450	480	432	20.3	0.73	0.80	0.80	0.60	0.22
Yield Grade	3.01	3.04	3.09	3.05	3.10	2.92	3.03	2.89	0.09	0.20	0.20	0.81	0.50	0.73

[1]Orthogonal contrasts were used to explore the linear and quadratic responses, and contrasts were also used to compare the control and 1, 2, and 3 g/d treatment groups.

[2]Calculated by back calculating from the USDA YG equation

[3]Marbling Score 400 = Small00, 500 = Modest00

Results

Results showed that feeding increasing amounts of rumen-protected lysine throughout the entire feeding period linearly decreased dry matter intake *(P* = 0.04; Table 2) and carcass adjusted average daily gain (*P* = 0.04) with no effect on feed conversion (*P* ≥ 0.23). Dry matter intake was lower for the 3 g/d treatment compared to the control (*P* = 0.03). Decreases in dry matter intake suggest a potential aversion to the Smartamine ML product. Carcass adjusted final body weight and thus hot carcass weight tended to linearly decrease (*P* = 0.07) as Smartamine ML increased in the diet, with no effect on other carcass measures including LM area, 12th rib fat, and marbling score (*P* ≥ 0.18).

During the first 64 days of the trial, average daily gain linearly decreased (*P* = 0.05) as Smartamine ML increased with a trend for feed conversion to linearly increase (*P* = 0.08) with no other impacts on performance (*P* ≥ 0.20). During the Optaflexx feeding period (d 163–195), dry matter intake linearly decreased (*P* = 0.01) as lysine increased in the diet. In addition, dry matter intake was lower for the 2 g/d treatment compared to the control (*P* = 0.01). Despite lower DMI, there was no effect on carcass adjusted average daily gain (*P* ≥ 0.51) or feed conversion (*P* ≥ 0.34).

Conclusion

Feeding supplemental lysine in finishing beef cattle diets that contained 15% modified distillers' grains plus solubles did not improve performance. Supplemental lysine reduced feed intake suggesting that excess lysine can impede performance in beef cattle. These results also suggest that with 15% modified distillers grains plus solubles in the diet (DM basis), cattle are supplied with enough lysine from rumen undegradable protein and microbial crude protein to satisfy lysine requirements.

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Effect of Corn Processing on Steer Performance and Fecal Starch Content

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Summary with Implications

Processing corn as high-moisture corn increases starch digestion and improves cattle efficiency when fed blended with dry-rolled corn in finishing rations. A finishing study evaluated the effect of corn processing method (dry-rolled corn or 2:1 high-moisture corn to dry-rolled corn blend) on performance of calf-fed steers. Corn processing method did not affect average daily gain; however, steers fed a high-moisture corn and dry-rolled corn blend consumed 1.1 lb/day less than steers fed a dry-rolled corn diet. Feeding high-moisture corn and dry-rolled corn blend diets improved feed efficiency by 5.2% compared to steers fed dry-rolled corn. Fecal starch content decreased by 31.3% when comparing cattle fed the high-moisture corn and dry rolled corn blend diet to cattle fed a dry-rolled corn diet.

Introduction

Increasing the extent of starch digestion in finishing rations can improve feed conversion and cattle performance. Processing corn as high-moisture corn increases ruminal starch digestibility by up to 37% in comparison to corn processed as dry-rolled corn (*2006 Nebraska Beef Cattle Report*, pp. 38–39). Due to increased starch degradation, feeding high-moisture corn improves finishing cattle performance by decreasing dry-matter intake and improving feed conversion when compared to dry-rolled corn (*2008 Nebraska Beef Cattle Report*, pp. 54–56). Feeding blends of high-moisture corn and dry-rolled corn improves feed conversion, with a 3:1 ratio of high-moisture corn to dry rolled corn optimizing feed conversion in finishing steers. The objective of this experiment was to evaluate the effect of feeding finishing diets containing either dry-rolled corn or a high-moisture corn and dry-rolled corn blend on steer performance, carcass characteristics, and fecal starch content during the finishing period.

Procedure

A finishing study was conducted utilizing 800 crossbred steers (666 ± 38 lb) fed for an average of 192 days. Prior to trial, steers were limit-fed at approximately 2% of body weight for five days to equalize gut fill. The limit-fed diet was comprised of 50% alfalfa hay and 50% Sweet Bran (Cargill Wet Milling; Blair, NE). Steers were divided into two starting blocks, and each block of steers were weighed for two consecutive days (d-2 and d-1 for the first half, d0 and d1 for second half). Individual weights were averaged to establish initial weight (666 lb. ± 38 lb). Steers were stratified by first day weights and blocked. Cattle were assigned randomly to pens within weight block and pens were assigned randomly to treatment. The adaption period of 25 days consisted of decreasing alfalfa haylage while increasing corn inclusion. Treatment diets consisted of either 70% dry-rolled corn (DRC) or a blend of 46.67% high-moisture corn and 23.33% DRC (HMC:DRC) (Table 1). Each treatment consisted of five weight blocks and 20 replications per treatment. Pens contained 20 steers and pen served as the experimental unit.

Steers were implanted with Revalor IS (Merck Animal Health) on days -1 and 1 (based on initial weighing). Cattle were reimplanted with Revalor 200 (Merck Animal Health) on days 70 and 71. Cattle were harvested one week apart at 188 and 195 days on feed. Steers were slaughtered at Greater Omaha. Hot carcass weight (HCW) and liver abscess scores were collected on the day of slaughter. After a 48-hour chill, USDA marbling score, longissimus muscle (LM) area, and 12th rib fat depth were recorded. Carcass adjusted final body weight (BW), average daily gain (ADG), and feed efficiency were calculated from final BW based on HCW adjusted to a 63% dress. Feed efficiency (G:F) were analyzed, but data are reported as feed conversion (F:G).

The MIXED procedure of SAS was used to analyze animal performance and carcass characteristics with pen as the experimental unit. Block was treated as a fixed effect.

Fecal samples were collected from the pen floor on days 47, 90, 135, and 181 while on finishing diets. Composites were dried for 48 hours in a 60°C forced air oven. Concentration of fecal starch was determined using the Megazyme total starch assay procedure utilizing the amyloglucosidase and α-amylase method. The GLIMMIX procedure of SAS was used to analyze fecal starch content as a repeated measure with pen as the experimental unit. Effects of corn processing method and time on fecal starch content were analyzed over both the entire feeding period and while steers were fed the finishing ration only.

High moisture corn and dry rolled corn samples were collected monthly to evaluate particle size using the sieve method.

Results

Regardless of treatment, cattle finished with a HCW of 853 lb ($P = 0.96$; Table 2). Steers fed HMC:DRC consumed 1.1 lb/day less than steers fed the DRC diet ($P < 0.01$). Average daily gain of steers fed DRC was not significantly different than ADG of steers consuming a HMC:DRC blend ($P = 0.91$). Feeding HMC:DRC improved feed efficiency by 5.2% ($P < 0.01$) compared to feeding DRC due to lower DMI and similar ADG overall for HMC:DRC. Corn processing did not impact marbling or LM area ($P > 0.58$). Steers fed HMC:DRC were slightly fatter at slaughter than steers fed DRC ($P = 0.04$; Table 2).

In the finishing period, a 31.3% reduc-

Table 1. Dietary treatment composition (DM basis) fed to finishing steers.

Ingredient	DRC[1]	HMC:DRC[2]
Dry-rolled corn	70.0	23.33
High-moisture corn	-	46.67
Sweet Bran	20.0	20.0
Wheat Straw	5.0	5.0
Supplement[3]	5.0	5.0

[1]DRC included in the diet on a DM basis at 70%

[2]HMC:DRC had HMC included at 46.47% and DRC included in the diet at 23.33% on a DM basis

[3] Supplement consisted of Rumensin (Elanco Animal Health) at 30g/ton of DM, Tylan (Elanco Animal Health) at 8.8 g/ton of DM, 0.65% urea, and a trace mineral + vitamin package

Table 2. Effect of corn processing on performance and carcass characteristics

Item	DRC[1]	HMC:DRC[2]	SEM	*P*-value
Pens	20	20		
Performance				
Initial BW, lb	673	673	0.4	0.73
Final BW, lb[3]	1354	1354	5.1	0.95
DMI, lb/d[3]	23.8	22.7	0.1	< 0.01
ADG, lb[3]	3.54	3.55	0.03	0.91
Feed:Gain[3 4]	6.72	6.39	-	< 0.01
Carcass Characteristics				
HCW, lb	853	853	3.21	0.96
Marbling[5]	524	523	5.05	0.83
LM area	13.8	13.9	0.08	0.58
12th Rib Fat	0.54	0.56	0.008	0.04

[1]DRC included in the diet on a DM basis at 70%

[2]HMC:DRC had HMC included at 46.47% and DRC included in the diet at 23.33% on a DM basis

[3]Calculated using hot carcass weight with a 63% dressing percentage adjustment

[4] Analyzed as Gain:Feed, reciprocal of Feed:Gain

[5]Marbling Score 500=Modest00, 600=Moderate00

Table 3. Effect of corn processing method on percent fecal starch during finishing period

Days on Feed	47	90	135	181	*P*-value
DRC[1]	18.76	24.46	20.91	24.96	<0.01
HMC:DRC[2]	15.03	16.56	13.19	16.44	

[1]DRC included in the diet on a DM basis at 70%

[2]HMC:DRC had HMC included at 46.47% and DRC included in the diet at 23.33% on a DM basis

Table 4. Corn particle size distribution of DRC and HMC with geometric mean diameter (GMD) and geometric standard deviation (GSD)

	DRC[1]		HMC[2]	
Screen Size, µm	Percent Retained	CV	Percent Retained	CV
6300	1.77	69.75	14.31	36.49
4750	25.94	20.22	37.87	5.75
3350	47.51	27.25	22.44	9.74
1700	17.11	39.93	11.92	16.48
1410	2.47	165.91	1.84	18.80
850	1.87	56.46	4.25	20.92
600	0.86	51.62	2.45	31.83
<600	1.99	54.25	4.92	21.61
GMD, µm	3486	-	2809	-

[1]DRC included in the diet on a DM basis at 70%

[2]HMC:DRC had HMC included at 46.47% and DRC included in the diet at 23.33% on a DM basis

tion in fecal starch content was observed when HMC:DRC was fed compared to the DRC diet ($P < 0.01$; Table 3). When evaluating corn particle size, high-moisture corn retained 12.54% more particles than DRC on the top screen (6300µm; whole corn) (Table 4). Corn processed as DRC had a numerically greater geometric mean diameter than HMC, with DRC having more particles retained on screens above 1700µm. These data suggest that HMC contained a greater proportion of whole kernels and fine particles than DRC.

Conclusion

Finishing steers on a HMC:DRC blend diet resulted in a 31.3% reduction in fecal starch compared to steers finished on a DRC diet. Feeding a HMC:DRC blend decreased intake and maintained similar gains, resulting in a 5.2% improvement in feed conversion when compared to steers fed DRC.

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Effect of Enogen Feed Corn Inclusion in Conventional and Natural Finishing Cattle Diets

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Summary with Implications

Increasing the extent of starch digestibility during finishing could allow producers to improve cattle efficiency. A finishing performance study was conducted to determine the effect of Enogen Feed Corn inclusion as dry-rolled corn and corn silage in comparison to a control corn hybrid within natural and conventional feeding programs for heifers and steers. Cattle in the conventional feeding program received implants and the ration included feed additives, while cattle on the natural program were not implanted and the ration did not contain feed additives. The inclusion of Enogen Feed Corn had no impact on steer or heifer finishing performance. The use of implants and feed additives in the conventional feeding program increased hot carcass weight 12.2% in steers and 7.0% in heifers. When compared to cattle in the natural program, feeding cattle in a conventional program improved feed conversion by 19.4% in steers and 13.0% in heifers.

Introduction

Inclusion of amylase enzymes in finishing rations can improve starch digestion and improve feed efficiency during the finishing period. Enogen Feed Corn (Syngenta Seeds, Inc.) contains an alpha amylase enzyme trait and improves total tract starch digestion when fed as dry-rolled corn with the inclusion of Sweet Bran (Cargill wet milling, Blair, NE) or modified distillers grains (*2016 Nebraska Beef Cattle Report*, pp. 139–142). The improvement in feed efficiency due to inclusion of Enogen Feed Corn as dry-rolled corn in finishing diets has been variable (*2016 Nebraska Beef Cattle Report*, pp. 135–138; *2016 Nebraska Beef Cattle Report*, pp. 143–145). The objective of this study was to evaluate the impact of feeding Enogen Feed corn as dry-rolled corn and corn silage within natural and conventional programs on steer and heifer finishing performance and carcass characteristics.

Table 1. Dietary treatment composition (DM basis) fed to finishing cattle

	Steers		Heifers	
Ingredient	Conventional[1]	Natural	Conventional[1]	Natural
Dry-Rolled Corn[2]	60	60	60	60
Corn Silage[2]	20	20	20	20
MDGS[3]	14	14	14	14
Supplement	6	6	6	6

[1] Rumensin-90 was formulated in the diet at 30 g/ton

[1] Tylan-100 was formulated in the diet at 8.8 g/ton

[1] MGA was formulated in the conventional heifer treatment diet at 0.5 mg/hd/d

[2]Cattle on the ENO treatment received the Enogen Feed Corn hybrid DRC and corn silage while cattle on the CON treatment received the control corn hybrid as DRC and corn silage

[3]MDGS = Modified distillers grains plus solubles

Procedure

Crossbred steers (n=400; initial BW= 843± 73 lb) and heifers (n=200; initial BW=728 ± 42 lb) were utilized in a 2 × 2 factorial design study at the University of Nebraska Panhandle Research and Extension Center (PREEC) near Scottsbluff, NE. Factors were corn hybrid type and feeding program. The factor of corn hybrid consisted of Enogen Feed Corn (EFC) inclusion as the dry-rolled corn (DRC) and silage source or a control corn hybrid as the DRC and silage source (CON). Each corn hybrid was fed within a natural feeding program, where the diet did not include additives or implants, or in a conventional feeding program where cattle received implants (Component implants; Elanco Animal Health) and the diet included Rumensin (Elanco Animal Health) at 30 g/ton of DM, Tylan (Elanco Animal Health) at 8.8 g/ton of DM, and MGA (Zoetis) fed to heifers only to provide 0.5 mg/heifer daily (Table 1).

Prior to trial initiation, cattle were limit-fed at approximately 2% of body weight for five days to equalize gut fill. The limit fed diet contained 80% alfalfa hay, 14% MDGS and 6% supplement. Cattle were weighed on d -1. Steers and heifers assigned to the conventional program were implanted on days 0 and 1 (Component TE-S and Component TE-H, for steers and heifers, respectively). Cattle were stratified by weight within sex and blocked by weight. Steers were then assigned randomly to pens within 5 weight blocks for a total of 40 pens and 10 replications per treatment. Heifers were assigned randomly to pens within 3 weight blocks for a total of 20 pens and 5 replications per treatment. Pens were assigned randomly to one of four treatments. Steers and heifers in the conventional program were reimplanted with Component TE-200 (Elanco Animal Health) on day 56.

Cattle were harvested by block at Tyson Fresh Meats, at 155, 175, and 183 d on feed. Hot carcass weight (HCW) and liver abscess scores were recorded on the day of slaughter. After a 48-hour chill, USDA marbling score, longissimus muscle (LM) area, and 12th rib fat depth were recorded. Carcass adjusted final body weight (BW), average daily gain (ADG), and feed efficiency were calculated from final BW based on HCW adjusted to a 63% dress. Feed efficiency (G:F) were analyzed, but data are reported as feed conversion (F:G).

The MIXED procedure of SAS was used

Table 2. Simple effect of program within sex on performance and carcass characteristics

	Steers		Heifers			*P*-value			
Item	CONV[1]	NAT[2]	CONV	NAT	SEM	S*P*E[3]	S*P[4]	Sex	Program
Pens	20	20	10	10					
Performance									
Initial BW, lb	844	843	728	728	1.3	0.71	0.74	<0.01	0.86
Final BW, lb[5]	1523	1357	1353	1263	12.5	0.14	<0.01	<0.01	<0.01
DMI, lb/d[5]	23.8	24.3	24.6	24.2	0.28	0.01	0.02	<0.01	<0.01
ADG, lb/d[5]	3.89	2.96	3.66	3.14	0.075	0.20	<0.01	0.49	<0.01
Feed:Gain[5 6]	6.61	8.20	6.71	7.71	-	0.99	<0.01	<0.01	<0.01
Carcass Characteristics									
HCW, lb	959	855	852	796	7.8	0.14	<0.01	<0.01	<0.01
Yield Grade	3.31	3.20	3.45	3.23	0.081	0.15	0.26	0.12	<0.01
Marbling[7]	564	593	583	575	13.8	0.06	0.09	0.82	0.38
LM area, in^2	14.4	13.2	13.3	12.9	0.18	0.34	<0.01	<0.01	<0.01
12th Rib Fat, in	0.57	0.52	0.65	0.56	0.021	0.16	0.21	<0.01	<0.01

[1]CONV = Conventional feeding program received implants and feed additives

[2]NAT = Natural feeding program did not receive implants or feed additives

[3]S*P*E = Sex × program × Enogen Feed Corn inclusion interaction

[4]S*P = Sex × program interaction

[5]Calculated using hot carcass weight with a 63% dressing percentage adjustment

[6] Analyzed as Gain:Feed, reciprocal of Feed:Gain

[7]Marbling Score 500=Modest00, 600=Moderate00

to analyze animal performance and carcass characteristics with pen as the experimental unit and block as a fixed effect. Data were analyzed as a 2 × 2 × 2 factorial assessing interactions between sex, program, and Enogen Feed Corn inclusion. When no interactions were detected, the main effects of Enogen Feed Corn inclusion, program, and sex were evaluated. Simple effects of program within each sex were evaluated when a significant interaction occurred.

Results

No significant feeding program × corn hybrid interactions ($P \geq 0.13$), or sex × corn hybrid interactions ($P \geq 0.12$) were observed. A sex × feeding program × corn hybrid ($P = 0.01$; Table 2) interaction was observed for DMI. Inclusion of Enogen Feed Corn in natural heifer diets tended to increase DMI by 0.25 lb/d ($P = 0.10$), while hybrid inclusion had no impact on DMI of heifers in the conventional feeding program. Feeding Enogen Feed Corn in conventional steer diets tended to increase DMI by 0.7 lb/d ($P = 0.06$) when compared to steers consuming the control corn hybrid diet. Corn hybrid had no impact on DMI when fed in natural steer diets ($P = 0.15$).

Significant sex × feeding program interactions were observed for carcass adjusted final BW, DMI, ADG, F:G, HCW, and LM area ($P < 0.01$). Gains of heifers on the natural program were 0.52 lb/d lower in comparison to heifers in the conventional feeding program ($P < 0.01$). Feeding steers in the natural program reduced ADG by 0.93 lb/d when compared to steers in the conventional program ($P < 0.01$). Carcass adjusted final BW decreased by 166 lb in natural steers and 90 lb in natural heifers compared to conventional programs ($P < 0.01$). Dry matter intake was similar between natural and conventional heifers ($P = 0.31$), while natural steers consumed 1.4 lb/d less than steers in the conventional program ($P < 0.01$). Feed conversions of conventional steers and heifers were not significantly different ($P = 0.96$) while feed conversion improved by 6.0% when comparing natural heifers to natural steers ($P < 0.01$). Compared to cattle in the natural program feed conversion improved by 13.0% when heifers were fed in a conventional program ($P < 0.01$) and 19.4% when steers were fed in a conventional program ($P < 0.01$). Hot carcass weights of steers on the conventional program were 104 lb heavier than HCWs of steers on the natural program. Feeding heifers in the conventional program increased HCW by 56 lb compared to heifers in the natural feeding program ($P < 0.01$). Yield grade and fat depth increased when cattle were fed in the conventional program ($P < 0.01$). Steers were leaner than heifers at slaughter, with 12th rib fat depth being significantly less in steers ($P < 0.01$). Inclusion of Enogen Feed Corn as DRC and silage in finishing heifers and steers decreased LM area by 2.3% compared to cattle fed the control DRC and corn silage ($P = 0.05$; Table 3).

Enogen Feed Corn processed as DRC retained 21% more particles than the conventional corn hybrid on the largest screen (6300 µm, whole corn) (Table 4). The control corn hybrid retained 14.9% more particles on the 3350 µm screen than Enogen Feed Corn. These data suggest Enogen Feed Corn may not have been processed to the extent that the control corn hybrid was processed.

Conclusion

The inclusion of Enogen Feed Corn had no effect on feed conversion in natural or conventional feeding programs. The incorporation of implants and feed addi-

Table 3. Main effect of Enogen Feed Corn inclusion as DRC and corn silage on performance and carcass characteristics

Item	CON[1]	EFC[2]	SEM	*P*-value
Pens	30	30		
Performance				
Initial BW, lb	746	745	0.8	0.44
Final BW, lb[3]	1331	1326	8.1	0.58
DMI, lb/d[3]	23.8	24.1	0.18	0.35
ADG, lb[3]	3.37	3.35	0.049	0.71
Feed:Gain[3 4]	7.16	7.28	-	0.22
Carcass Characteristics				
HCW, lb	839	835	5.1	0.57
Yield Grade	3.19	3.25	0.052	0.30
Marbling[5]	572	565	8.9	0.53
LM area, in[2]	13.4	13.1	0.12	0.05
12th Rib Fat, in	0.55	0.56	0.014	0.56

[1]CON = Control corn hybrid included in the diet as DRC and corn silage

[2]EFC = Enogen Feed Corn hybrid included in the diet as DRC and corn silage

[3]Calculated using hot carcass weight with a 63% dressing percentage adjustment

[4] Analyzed as Gain:Feed, reciprocal of Feed:Gain

[5]Marbling Score 500=Modest00, 600=Moderate00

Table 4. Corn particle size distribution of CON DRC and EFC DRC with geometric mean diameter (GMD) and geometric standard deviation (GSD)

	CON[1] DRC		EFC[2] DRC	
Screen Size, µm	Percent Retained	CV	Percent Retained	CV
6300	3.07	69.81	24.09	8.48
4750	29.49	28.98	32.45	15.70
3350	44.48	24.66	29.58	22.74
1700	16.01	2.98	9.56	8.47
1410	1.38	21.97	1.08	7.60
850	2.32	28.82	1.44	21.06
600	0.84	6.51	0.72	59.90
<600	2.41	6.85	1.08	32.85
GMD, µm	3478	-	2848	-
GSD, µm	1445	-	722	-

[1]CON = Control corn hybrid included in the diet as DRC

[2]EFC = Enogen Feed Corn hybrid included in the diet as DRC

tives within the finishing period increased carcass adjusted final BW, HCW, and ADG leading to improved feed conversion for both steers and heifers.

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Effects of Corn Processing and Silage Inclusion in Feedlot Diets on Steer Performance

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Summary with Implications

A feedlot study compared the effects of corn silage inclusion on steer performance and carcass characteristics within dry-rolled corn diets and steam-flaked corn diets. Treatments included four corn silage inclusions as 0, 15, 30, or 45% of dry matter in both steam-flaked corn and dry-rolled corn base diets. Feeding a steam-flaked based corn diet increased average daily gain by 7.8% and improved feed conversion by 6.8% when compared to steers fed a dry-rolled corn diet. As corn silage inclusion increased, feed conversion increased linearly. When fed to the same days on feed carcass adjusted final body weight, hot carcass weight, and average daily gain responded quadratically: steers fed 15% and 30% corn silage gained faster and were heavier than steers fed 0% or 45% corn silage. Feeding steam-flaked corn improved gain and feed conversion compared to dry-rolled corn. Regardless of corn processing method, including corn silage in the diet at 15 or 30% of dry matter maximized gain but as expected, feed conversion was lowest with no roughage.

Introduction

Corn silage is an abundant and cost-effective roughage source within the Midwest.

Increasing corn silage inclusion from 15% to 45% while replacing dry rolled corn in finishing rations resulted in poorer feed conversion and slower average daily gain (*2013 Nebraska Beef Cattle Report*, pp. 74–75). Previous studies have shown that when feeding corn silage at 12–15% of diet dry matter (DM), cattle perform similarly to steers fed alfalfa hay at 7.5–8% of diet DM (*2019 Nebraska Beef Cattle Report*, pp. 63–65; *2007 Nebraska Beef Cattle Report*, pp. 29–32). Consequently, as corn grain price increases it may become more economically efficient to reduce ration price by increasing corn silage inclusion (*2021 Nebraska Beef Cattle Report*, pp. 69–71). The objective of this study was to determine optimal corn silage inclusion in dry-rolled corn and steam-flaked corn finishing diets on finishing performance and carcass traits.

Table 1. Diet composition on a DM basis fed to finishing steers

Corn Processing Method	DRC				SFC			
Corn Silage Inclusion, %	0	15	30	45	0	15	30	45
Dry-Rolled Corn	79	64	49	34	-	-	-	-
Steam Flaked Corn	-	-	-	-	79	64	49	34
Corn Silage	0	15	30	45	0	15	30	45
Modified Distillers Grains	15	15	15	15	15	15	15	15
Supplement[2]	6	6	6	6	6	6	6	6

[1] Diets were formulated to include Rumensin (Elanco Animal Health) at 30 g/ton of DM and Tylan (Elanco Animal Health) at 8.8 g/ton of DM

[2]Supplement included urea at 1% of diet DM, trace mineral and vitamins

Procedure

A randomized block design finishing study was conducted at the University of Nebraska Panhandle Research and Extension Center (PREEC) in Scottsbluff, NE. Crossbred steers (n = 480; initial BW = 856± 37 lb) were utilized in 2 × 4 factorial arrangement of treatments with 6 replications per simple effect treatment. Treatments consisted of four inclusions of corn silage (0%, 15%, 30%, or 45%) within a dry-rolled corn (DRC) or steam-flaked corn (SFC) diet. Steers were limit-fed at 2% of BW for five days prior to initial weighing to equalize gut fill. The limit-fed diet was comprised of 40% corn silage, 40% alfalfa hay, 14% modified distillers grains, and 6% supplement. Cattle weights were collected on two consecutive days, following limit feeding, and averaged to determine initial body weight (BW). Steers were stratified by first day weights and sorted into 4 weight blocks. Cattle were assigned randomly to pens within weight block. Pens were assigned randomly to one of eight treatments. Each pen contained 10 steers for a total of 48 pens with pen serving as the experimental unit. Cattle were implanted with Revalor XS (Merk Animal Health) on day 0. The adaptation period included 5 steps over 28 days. On day 1, all steers received 19% corn, 15% modified distillers grains, and 20% alfalfa hay for the first step lasting 7 days. The second step increased corn silage to 45% for only the 45% corn silage inclusion treatment diets, with 10% alfalfa hay, 24% corn, and 15% modified distillers grains. In the second step all other treatment diets consisted of 30% corn silage, 10% alfalfa hay, 39% corn, and 15% modified distillers grains. Cattle on the 30% and 40% corn silage treatments started the finishing ration (Table 1) in the third step. The rest of the treatment diets reduced corn silage inclusion over the last 2 steps while increasing corn until reaching their respective corn silage inclusion levels (0 and 15%).

Steers were fed for 125 days and slaughtered at Greater Omaha. Hot carcass weight (HCW) and liver abscess scores were collected on the day of slaughter. After a 48-hour chill, USDA marbling score, longissimus muscle (LM) area, and 12th rib

Table 2. Simple effect of silage inclusion within corn processing method on steer performance and carcass characteristics

	DRC				SFC					*P*-value
	0	15	30	45	0	15	30	45	SEM	Interaction
Pens	6	6	6	6	6	6	6	6		
Performance										
Initial BW, lb	855	859	858	856	859	858	855	859	1.7	0.15
Final BW[1], lb	1297	1311	1331	1298	1331	1367	1351	1338	9.1	0.27
DMI, lb/d	22.6	23.5	25.7	26.3	22.2	24.7	25.7	26.7	0.28	0.04
ADG[1], lb/d	3.55	3.62	3.79	3.54	3.77	4.06	3.97	3.83	0.070	0.26
Feed:Gain[1 2]	6.37	6.49	6.80	7.44	5.90	6.08	6.48	6.96	-	0.80
Carcass Characteristics										
HCW, lb	817	826	839	818	838	861	851	843	5.7	0.26
LM Area, in^2	13.3	13.0	13.3	12.9	13.4	13.3	13.0	13.1	0.14	0.15
Marbling[3]	512	552	559	499	529	570	558	531	17.1	0.82
Fat Thickness, in	0.55	0.61	0.56	0.56	0.56	0.65	0.66	0.59	0.019	0.17
Liver Abscess[4], %	11.7	5.0	10.0	3.3	20.0	6.7	5.0	8.3	-	-

[1] Calculated using hot carcass weight with a 63% dressing percentage adjustment

[2]Analyzed as Gain:Feed, reciprocal of Feed:Gain

[3] Marbling Score 500=Modest00, 600=Moderate00

[4] Liver abscess scores were analyzed in SAS as a binomial distribution, corn silage inclusion x corn processing interaction was not significant (P = 0.38)

Table 3. Main effects of corn processing method on steer performance and carcass characteristics

	Corn Processing Method			
	DRC	SFC	SEM	*P*-value
Pens	24	24		
Performance				
Initial BW, lb	857	858	0.9	0.40
Final BW[1], lb	1310	1347	4.6	<0.01
DMI, lb/d	24.5	24.8	0.14	0.14
ADG[1], lb/d	3.62	3.91	0.036	<0.01
Feed:Gain[1 2]	6.77	6.35	-	<0.01
Carcass Characteristics				
HCW, lb	825	848	2.9	<0.01
LM Area, in.	13.1	13.2	0.75	0.33
Marbling[3]	530	547	8.7	0.18
Fat Thickness, in.	0.57	0.62	0.010	<0.01
Liver Abscess[4], %	7.5	10.0	-	-

[1] Calculated using hot carcass weight with a 63% dressing percentage adjustment

[2] Analyzed as Gain:Feed, reciprocal of Feed:Gain

[3] Marbling Score 500=Modest00, 600=Moderate00

[4] Liver abscess scores were analyzed in SAS as a binomial distribution, effect of corn processing method was not significant (P = 0.42)

fat depth were recorded. Carcass adjusted final body weight (BW), average daily gain (ADG), and feed efficiency were calculated from final BW based on HCW adjusted to a 63% dress. Feed efficiency (G:F) were analyzed, but data are reported as feed conversion (F:G).

The MIXED procedure of SAS was used to analyze animal performance and carcass characteristics with pen as the experimental unit. Liver abscess scores were analyzed as a binomial distribution using PROC GLIMMIX procedure of SAS. Block was treated as a fixed effect. Assessing interactions between corn processing and corn silage inclusion, data were analyzed as a 2×4 factorial. In cases where no interaction was detected, the main effects of corn processing or corn silage inclusion were evaluated. Orthogonal contrasts were utilized to evaluate linear, quadratic, and cubic effects of corn silage inclusion.

Results

A significant interaction between corn silage inclusion and corn processing was observed for DMI ($P = 0.04$). As corn silage inclusion increased in the diet, DMI also increased linearly ($P < 0.01$; Table 2) for both corn processing methods. Dry matter intake was not significantly different between SFC and DRC fed cattle at 0% ($P = 0.33$), 30% ($P = 0.90$), or 45% ($P = 0.31$) corn silage inclusion. The interaction ($P = 0.04$) is likely due to DMI of cattle fed 15% silage, as cattle fed DRC consumed less than cattle on the SFC diet ($P < 0.01$). No significant corn silage inclusion by corn processing method interactions were observed for any other performance or carcass traits ($P > 0.15$), thus, only main effects will be presented.

Feeding SFC increased final BW and HCW when compared to steers in the DRC treatment ($P < 0.01$) (Table 3). Cattle fed SFC gained 7.8% more ($P < 0.01$) and feed conversion was improved by 6.8% ($P < 0.01$) compared to steers fed DRC. As a

Table 4. Main effects of corn silage inclusion on steer performance and carcass characteristics

	Corn Silage Inclusion, %					*P*-value		
	0	15	30	45	SEM	Linear	Quad.	Cubic
Pens	12	12	12	12				
Performance								
Initial BW, lb	857	859	857	857	1.2	0.98	0.67	0.24
Final BW[1], lb	1314	1339	1341	1318	6.4	0.61	<0.01	0.90
DMI, lb/d	22.4	24.1	25.7	26.5	0.20	<0.01	0.02	0.39
ADG[1], lb/d	3.66	3.84	3.88	3.69	0.050	0.59	<0.01	0.74
Feed:Gain[1 2]	6.13	6.28	6.64	7.20	-	<0.01	<0.01	0.97
Carcass Characteristics								
HCW, lb	828	843	845	831	4.1	0.61	<0.01	0.91
LM Area, in.	13.3	13.2	13.1	13.0	0.10	0.02	0.63	0.85
Marbling[3]	520	560	558	515	17.1	0.73	<0.01	0.99
Fat Thickness, in.	0.56	0.63	0.61	0.58	0.014	0.53	<0.01	0.28
Liver Abscess[4], %	15.8	5.8	7.5	5.8	-	-	-	-

[1] Calculated using hot carcass weight with a 63% dressing percentage adjustment

[2] Analyzed as Gain:Feed, reciprocal of Feed:Gain

[3] Marbling Score 500=Modest00, 600=Moderate00

[4] Liver abscess scores were analyzed in SAS as a binomial distribution, effect of corn silage inclusion was significant (P = 0.03)

result of greater gain, fat depth ($P < 0.01$) was greater for cattle fed SFC compared to DRC treatments.

Feed conversion responded quadratically as silage inclusion in the diet increased with feed conversion being similar for cattle in the 0% and 15% silage inclusion treatments and increasing as silage inclusion increased in the 30% and 45% silage inclusion treatments ($P < 0.01$) (Table 4). Quadratic trends were observed for final BW, HCW, ADG, marbling, and fat depth ($P < 0.01$). Steers fed 15% or 30% corn silage gained faster and were heavier than those fed 0% or 45% corn silage. Corn processing method had no impact on liver abscess scores (P = 0.42). The incidence of liver abscesses increased in cattle fed 0% corn silage when compared to cattle fed 15, 30, or 45% corn silage (P = 0.03).

Conclusion

Feeding SFC resulted in a 7.8% increase in ADG and a 6.8% improvement in F:G. Corn silage inclusion had similar effects on performance in both DRC diets and SFC diets. In diets containing either DRC or SFC, corn silage can be included at up to 30% of the ration without negative impacts on steer performance.

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Quantifying Residual Feed in a Fence-line Feedlot Bunk using Depth Camera Imaging Techniques

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Summary with Implications

Feed bunk management requires intensive labor and relies on manual observation to estimate the amount of residual feed in the bunk. Alternative and innovative technologies were used to estimate the weight of residual feed in a concrete fence-line bunk using a depth camera. Depth cameras capture the distance between the camera and the object in their field of view. This study used a time-of-flight depth camera (Azure Kinect, Microsoft) to estimate the weight of residual feed in a partial fence-line concrete bunk using 11 common feed ingredients. The depth camera was fastened approximately 3.3 ft above the center of the bunk to collect images for individual ingredients added at a constant weight increment of 2.2 or 4.5 lb. The feed ingredients inside the bunk were stirred randomly after each picture collection to simulate the shape of residual feed after cattle's feeding event. Individual ingredients were then weighed using a scale for comparison with the image-estimated weights. Linear regression showed that the scale-measured weights and image-estimated weights were linearly related, with an R^2 ranging from 0.9833 to 0.9992. Results indicate that depth cameras are capable of accurately estimating the weight of residual feed in the bunk. Overall, this experiment demonstrates a first step in the development of feed bunk management tools using precision livestock management techniques.

Table 1. Eleven commonly used ingredients in Nebraska feedlot mixed diets. The bulk densities of ingredients ranged from 2.56 to 40.2 lb/ft^3

Ingredient	Bulk density (lb/ft^3)	Actual weight measurement range (lb)	Weight increment during image collection (lb)
Low bulk density ingredients			
Corn Stalks (CSt)[2]	2.55	0.7–20.23	2.2
Wheat Straw (WB)[2]	2.62	0.88–20.26	2.2
Grass Hay (GH)[2]	4.27	1.96–20.33	2.2
Alfalfa Hay (AH)[2]	5.09	0.95–20.15	2.2
Corn Silage (CSi)[1]	14.1	0.77–20.26	2.2
High bulk density ingredients			
Sweat Bran (SB)	23.47	3.4–50.3	4.5
Steam Flaked Corn (SF)	24.64	2.98—52.55	4.5
Dried Distiller's Grains (DDG)	34.54	1.5–50.3	4.5
High Moisture Corn (HMC)[1]	35.33	3.53–50.3	4.5
Modified Distiller's Grains (MDG)[1]	36.06	0.37–50.16	4.5
Dry Rolled Corn (DRC)	40.2	3.99–50.22	4.5

[1]ingredient had some mold present while collecting bulk density

[2]ingredient contained dust while collecting bulk density

Introduction

Precision Livestock Farming (PLF) has the potential to provide solutions to alleviate challenges that the U.S. beef industry is facing by using advanced technology as management tools. For the U.S. cattle industry, there were about 13.4 million head of cattle and calves on feed for slaughter in 2021. These cattle go through feedlots for an intensive feeding period that can range from 90 to 200 days. To maintain appropriate daily intake of the cattle and make prompt decisions on the next-day feed delivery, feedlot managers rely on manual observations of skilled workers as a feed bunk management protocol. This management protocol is prone to error and can cause feed waste that tends to increase the cost of production. The objective of this experiment was to develop image processing algorithms to predict the weight of residual feed in the bunk using depth images.

Procedure

Eleven common feed ingredients were used in this experiment: dried distillers' grains (DDG), alfalfa hay (AH), corn silage (CSi), corn stalks (CSt), dry rolled corn (DRC), high moisture corn (HMC), grass hay (GH), modified distiller's grains (MDG), sweet bran (SB), steam flaked corn (SF), and wheat straw (WS). Table 1 shows each ingredient's bulk density and the measured range of the actual weights during data collection. Bulk densities were measured by weighing a nine-liter sample of each feed ingredient. For each bulk density measurement, the ingredients were carefully added in the bucket to reduce compaction and over-packing of the bucket. The ingredients were divided into two categories based on their bulk densities (low bulk density ingredients and high bulk density ingredients). The low bulk density ingredients ranged from 2.56 to 14.1 lb/

ft³ and were imaged with a 2 lb weight increment, while the high bulk density ingredients ranged from 23.5 to 40.2 lb/ft³ and were imaged with about a 4 lb weight increment (Table 1).

The time-of-flight depth camera was used to measure the distance between the camera and the surface of the ingredients. The depth camera was centrally positioned on top of a fence-line feed bunk facing downwards to capture a two-feet section of the concrete bunk. The camera was positioned at least three feet from the base of the bunk. For each weight level, ten depth images were captured for the residual ingredients. Five depth images with best image quality and pixel consistency, representing different feeding events were selected at each weight level for image processing. An image processing program was developed using the MATLAB data analytic software to estimate the volume of the ingredient using the depth images, and to multiply the estimated volumes to their corresponding measured bulk densities. After the estimated weights were predicted by the image processing program, the image-estimated weights were compared to the scale-measured weights. Linear regression was developed for each ingredient and used to find the R^2 and the *P*-value of the relationship between the scale-measured weights and image-estimated weights.

Results

The scale-measured weights were plotted against the image-estimated weights for each ingredient to evaluate the relationship between the two variables, and the results are shown in Fig. 1. The average coefficient of determination (R^2) for all ingredients was 0.99. The linear relationship between the scale-measured weights and the image-estimated weights was strong and significant (*P*-value < 0.0001) for all ingredients. Fig. 1 shows that the R^2 of all the ingredients ranged from 0.9833 for GH to 0.9992 for SF and a *P*-value < 0.0001. The ingredients with lower R^2 values were GH, DRC, and SB, with a value of 0.9833, 0.9876 and 0.9888, respectively. SF had the highest R^2 value of 0.9992, followed by HMC and MDG with an R^2 value (= 0.9984). Other ingredients like AH, CSi, and WS had a high R^2 of 0.9972, and DDG and CSt had an R^2 of 0.9963 and 0.9949, respectively. The results from this study show that the depth camera can estimate 99.4% of the residual feed weight in the fence-line concrete bunk. In future experiments, depth cameras will be used to evaluate the accuracy to quantify the volume and estimate the weight of mixed diets in the bunk.

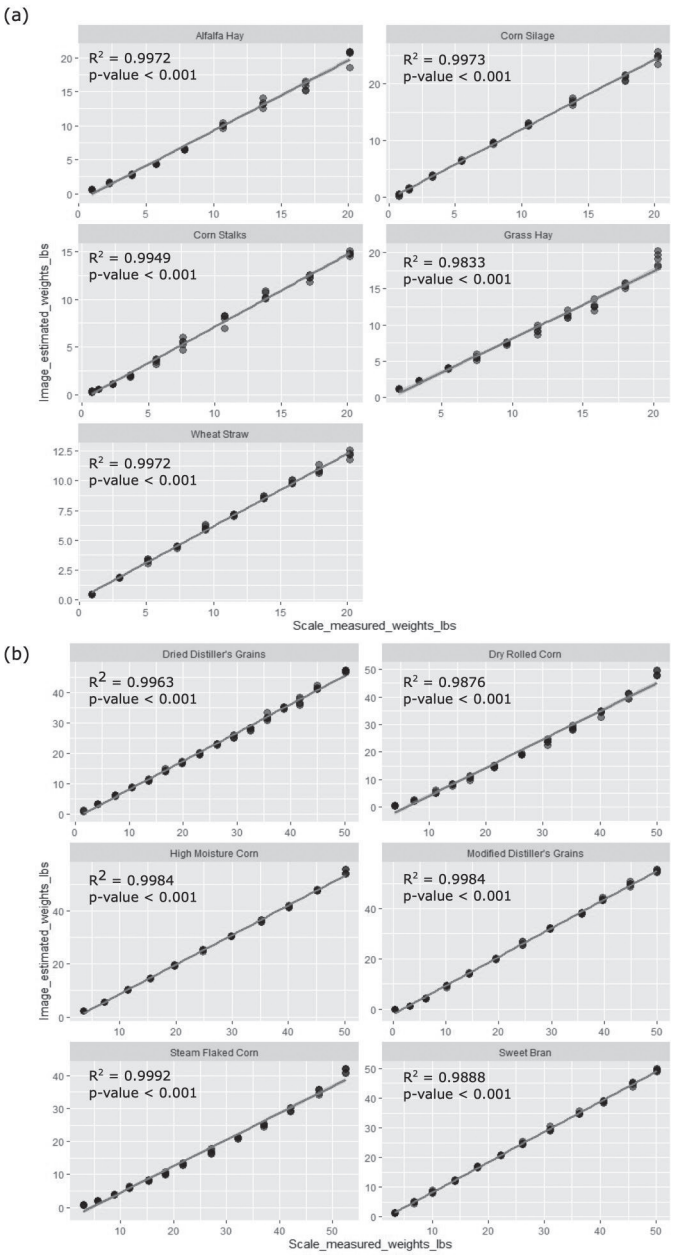

Figure 1. Comparison of the scale-measured weights (X-axis) and the image-estimated weights (Y-axis) of the eleven ingredients. (a) shows the linear relationship for the low bulk density ingredients, and (b) shows the linear relationship for ingredients with high bulk densities. The measured weight range ranged from 0.7 to 20.23 lb for (a) low bulk density ingredients, while the measured weight range for high bulk density ingredients (b) ranged from 1.5 to 50.3 lb. The *P*-value was smaller than 0.0001 for all the ingredients.

Conclusion

This experiment demonstrated that the depth sensing method is a promising tool to estimate the weight of residual feed in a concrete fence-line feedlot bunk. This tool offers an alternative solution to increase the capacity and the production efficiency in commercial feedlots. With this tool, managing a large quantity of feed bunks at once may require less labor and provide accurate predictions of residual feed in the bunk. For large feedlots, accurate residual feed predictions can reduce the cost of production by allocating feed resources more efficiently and reducing feed spoilage and waste.

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Effect of Alga Bio 1.0 on Reducing Enteric Methane Emissions from Cattle

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Summary with Implications

An experiment was conducted to determine the effect of Alga Bio 1.0 inclusion on methane and carbon dioxide emissions along with diet digestibility. Three treatments were evaluated with 0, 69, and 103 grams per day Alga Bio 1.0 fed as a top dress in a corn-based diet. Indirect calorimetry headboxes were utilized to evaluate gas production with 12 cows in 4 replicated 3x3 Latin squares. There was a 39% reduction in methane per lb of dry matter intake for cattle fed 69 g of Alga Bio 1.0 and 63% reduction when cattle were fed 103 g of Alga Bio 1.0 daily compared to the control treatment. Both dry matter intake and organic matter intake were reduced by 13% with Alga Bio 1.0 inclusion, but the treatments did not affect the digestibility of dry matter or organic matter. Gross and digestible energy were not affected by Alga Bio 1.0 inclusion. Although this strain of algae is not FDA approved for feeding to cattle, the research shows great potential of Alga Bio 1.0 as a methane mitigation strategy.

Introduction

Greenhouse gas emissions are a concern related to future climate and global warming potential. Methane (CH_4) emissions are one gas that the agricultural industry will target, and beef cattle are implicated due to enteric fermentation. Because methane has a short life span (10 to 12 years in the atmosphere), reductions will have an immediate impact on the climate. Cattle also experience an energetic loss, 2 to 12% of dietary energy, when producing methane during ruminal fermentation.

Some types of algae have been proposed as a feed additive to reduce methane production in the rumen. Algae is a broad category of aquatic plants, one of which is seaweed. The active ingredient bromoform is concentrated in some species of red seaweed (Asparagopsis taxiformis is perhaps the most widely researched), and blocks the pathway for methane production during ruminal fermentation. Although the product used in this experiment is not Asparagopsis taxiformis, it was inspired by the seaweed and acts in a similar way. The objective of this experiment was to evaluate the effects of Alga Bio 1.0 on diet digestibility and impacts on methane production in cattle.

Procedure

An experiment using indirect calorimetry (headboxes) was conducted at the University of Nebraska-Lincoln Animal Science metabolism area in Lincoln, NE. Twelve non-lactating, open Jersey cows (previously trained for the headboxes) were used in a 3-period replicated design. Cows were blocked by intake and assigned randomly within 4 blocks to 1 of 3 treatments (4 cows per treatment). Each block was replicated three times with each cow receiving each of the treatments. Treatments included 0, 69 and 103 g (DM basis) of Alga Bio 1.0 daily provided as a top-dress. This was equal to approximately 0, 0.4, and 0.6% of diet DM. Modified distillers grains plus solubles
(MDGS) was used as a carrier and was displaced with the Alga Bio 1.0 to equal one-pound DM of top-dress. Because this product is not FDA approved for feeding to cattle, no milk or meat from these animals entered the food supply chain.

Cattle were housed in individual stalls and fed once daily in the morning with ad libitum access to feed and water. Feed refusals were collected each day before feeding. Diet consisted of 60% dry-rolled corn, 20% corn silage, 15% MDGS, and 5% supplement (DM basis; Table 1). Cows were adapted to high-grain diets prior to start of the experiment. Each period was 21 days with diet samples, orts, and total feces collected for the last 4 days of each period. Samples were dried for 48 hr at 60˚C in a forced-air oven and ground through a 1-mm screen. Samples were analyzed for DM, organic matter (OM), and energy using a bomb calorimeter.

Table 1. Diet composition.

Ingredient, % of DM[1]	
Dry-rolled corn	60
Corn Silage	20
Modified distillers grains plus solubles	15
Supplement	5
Fine ground corn	2.2025
Limestone	1.68
Tallow	0.125
Urea	0.60
Salt	0.30
Trace mineral premix	0.05
Vitamin ADE	0.015
Rumensin-90[2]	0.0165
Tylan-40[3]	0.011

[1]All treatments received the same basal diet with the addition of Alga Bio 1.0 as a top dress (0, 69, or 103 g/d) mixed with modified distillers grains plus solubles at 1 lb DM/cow daily

[2]Supplement formulated to provide 30 g/ton of Rumensin® (Elanco Animal Health, DM basis)

[3]Supplement formulated to provide 8.8 g/ton of Tylan® (Elanco Animal Health, DM basis)

Gas emissions (methane and carbon dioxide) were collected using indirect headbox style calorimeter and emissions were calculated using a gas analyzer. Cows were in headboxes for two, non-consecutive 23-hr periods (adjusted to 24-hr) and gas samples were collected in foil bags that filled evenly throughout the time frame. Gas measurements were averaged per cow for one value per period. Dry matter intake (DMI) of the cows during the 4 days of

Table 2. Effect of Alga Bio 1.0 inclusion on greenhouse gas emissions

	Treatment[1]				
	Control	69 g/d	103 g/d	SEM	*P*-value
CH_4, g/day	164.9[a]	88.2[b]	44.4[c]	15.6	< 0.01
CH_4, g/lb of DMI	7.94[a]	4.84[b]	2.91[c]	0.8	< 0.01
CO_2, g/day	8420[a]	7844[a]	7728[b]	424.1	0.08
CO_2, g/lb of DMI	407.6	416.6	428.4	20.4	0.39
O_2 consumption, g/day	5729	5065	5430	362.4	0.26
O_2 consumption, g/lb of DMI	281.8	265.2	296.5	22.6	0.39
RQ[2]	1.04	1.02	1.02	0.02	0.32

[1]All treatments received the same basal diet with the addition of Alga Bio 1.0 as a top dress (0, 69, or 103 g/d) mixed with modified distillers grains plus solubles at 1 lb DM/cow daily. The Alga Bio 1.0 inclusion was approximately 0.4 and 0.6% of diet DM.

[2]RQ = respiratory quotient, Liters per day of CO_2 production / Liters per day of O_2 consumption

[a,b,c] Means in row with unique superscripts are different ($P \leq 0.05$)

Table 3. Effect of Alga Bio 1.0 inclusion on intake, digestibility, and energy

	Treatment[1]				
	Control	69 g/d	103 g/d	SEM	*P*-value
Performance					
BW, lb	1086	1077	1081	42.1	0.66
BCS[2]	3.9	3.8	3.8	0.2	0.32
Intake and Digestibility					
Dry Matter Intake, lb/d	21.4[a]	19.2[b]	18.5[b]	1.4	0.01
Digestibility, %	70.6	68.9	68.6	2.4	0.51
Organic Matter Intake, lb/d	20.5[a]	18.3[b]	17.9[b]	1.4	0.01
Digestibility, %	75.2	74.7	74.7	1.8	0.89
Energy					
Gross Energy, Mcal/lb	1.99	2.00	1.99	0.01	0.44
Digestible Energy, Mcal/lb	1.44	1.42	1.43	0.03	0.67
DE/GE	0.72	0.71	0.71	0.02	0.66

[1]All treatments received the same basal diet with the addition of Alga Bio 1.0 as a top dress (0, 69, or 103 g/d) mixed with modified distillers grains plus solubles at 1 lb DM/cow daily. The Alga Bio 1.0 inclusion was approximately 0.4 and 0.6% of diet DM.

[2] Body Condition Score was performed using a 5-point scale common in the dairy industry.

[a,b,c] Means in row with unique superscripts are different ($P \leq 0.05$)

collections was used for reporting gas emissions on a per lb DMI basis.

Digestibility and gas emissions were analyzed using the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). Cow within period was the experimental unit. Cow and period were random effects and treatment was a fixed effect. Differences were considered significant if $P \leq 0.05$.

Results

The inclusion of Alga Bio 1.0 in the diet decreased methane production measured as g/d ($P < 0.01$; Table 2) and g/lb DMI ($P < 0.01$). There was a 39% reduction in methane emissions expressed as g/lb of DMI with 69 g Alga Bio 1.0 inclusion and 63% reduction (g/lb of DMI) with 103 g of Alga Bio 1.0 inclusion compared to the control diet. Methane emissions reported as g/d were reduced 46% with 63 g Alga Bio 1.0 and 73% with 103 g Alga Bio 1.0. Emissions of carbon dioxide (CO_2; g/d) tended ($P = 0.08$) to be lower for cattle receiving 103 g of Alga Bio 1.0, but did not differ when calculated as g/lb DMI ($P = 0.39$). Oxygen consumption (O_2) amounts did not differ between treatments for g/day ($P = 0.26$) and g/lb DMI ($P = 0.39$). Respiratory quotient (RQ; a measure of basal metabolic rate) was not significantly impacted ($P = 0.32$) by the treatments.

Alga Bio 1.0 inclusion did influence DMI ($P = 0.01$; Table 3) with the Alga Bio 1.0 treatments having lower DMI compared to the control. There was no difference in DM digestibility among the treatments ($P = 0.51$). Similar to DM, OMI was affected by the inclusion of Alga Bio 1.0 ($P = 0.01$), but OM digestibility was not influenced by the treatments ($P = 0.89$). Gross energy expressed as Mcal/lb was not affected by the inclusion of Alga Bio 1.0 ($P = 0.44$). Digestible energy (Mcal/lb) was not significantly different ($P = 0.67$) between treatments.

Conclusion

Cattle supplemented with Alga Bio 1.0 at 69 or 103 g/d had lower methane emissions compared to a dry rolled corn control diet. There was no significant impact on carbon dioxide emissions (g/lb of DMI). Intake was significantly decreased with the addition of Alga Bio 1.0, but digestibility and dietary energy were not impacted. Alga Bio 1.0 shows promise as a feasible methane mitigation tool when included in cattle diets as a feed additive; however, FDA approval is needed prior to use by producers.

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Impact of Pistachio Shell Biochar in Finishing Beef Cattle Diets

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Summary with Implications

A 190-day finishing experiment was conducted to evaluate effects of feeding biochar on methane and carbon dioxide production, animal performance and carcass traits in beef steers. A high concentrate feedlot diet was used, and two dietary treatments were compared, 0 or 1% biochar as % of diet dry matter. Cattle were monitored using a calorimetry emissions barn to quantify production of methane and carbon dioxide. There were no differences in emissions, performance, or carcass characteristics for cattle fed the control diet or with biochar supplemented into the diet.

Introduction

Greenhouse gas emissions have been linked to global climate changes, specifically methane (CH_4) and carbon dioxide (CO_2). Within the agricultural industry, a primary goal has been to reduce methane emissions from beef cattle, as methane produced through enteric fermentation within the rumen is eructated into the atmosphere. This is a naturally occurring process but also an energetic expense to the animal.

Biochar is made from organic substances exposed to high temperatures producing a charcoal-like material and converting carbon into a more stable form. There are two different processing methods: gasification and pyrolysis. Gasification converts biomass primarily into syngas using high temperatures (600–900ºC) and oxidizing agents such as oxygen, steam, or CO_2. The pyrolysis method converts biomass at lower temperatures of 350–600ºC and does not include an oxidizing agent. While *in vitro* data have shown a decrease in methane with the addition of biochar, *in vivo* data have shown biochar fed at 0.8 to 1% of the diet did not reduce emissions using headbox calorimetry (*2019 Nebraska Beef Cattle Report*, pp. 56–59) or in a production setting using pen calorimetry chambers and a variety of beef cattle diets (*2021 Nebraska Beef Cattle Report*, pp 31–32; *2022 Nebraska Beef Cattle Report*, pp. 77–78). The objective of this study was to evaluate the effect of biochar made by gasification and supplemented at 1% of diet dry matter (DM) on methane (CH_4) and carbon dioxide (CO_2) production, cattle performance, and carcass characteristics.

Table 1. Diet composition (% of DM) fed to finishing steers

Ingredient, %	Control	Biochar
Dry-rolled corn	35	34.5
High moisture corn	35	34.5
Modified distillers grains plus solubles	20	20
Corn residue	5	5
Biochar—pistachio shells[1]	-	1
Supplement	5	5
Fine ground corn	2.3125	2.3125
Limestone	1.67	1.67
Tallow	0.125	0.125
Urea	0.50	0.50
Salt	0.30	0.30
Trace mineral premix	0.05	0.05
Vitamin ADE	0.015	0.015
Rumensin-90[2]	0.0165	0.0165
Tylan-40[3]	0.011	0.011

[1]Displaced corn by 1% of diet DM

[2]Supplement formulated to provide 30 g/ton of Rumensin® (Elanco Animal Health, DM basis)

[3]Supplement formulated to provide 8.8 g/ton of Tylan® (Elanco Animal Health, DM basis)

Procedure

A finishing cattle experiment was conducted at the Eastern Nebraska Research, Extension and Education Center near Mead, NE. One hundred twenty-eight steers (initial BW = 725 lb; SD = 41 lb) were utilized in a randomized block design. Cattle were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) on a DM basis at 2% of body weight (BW) for 5 d to equalize gastrointestinal fill. Weights were taken on two consecutive days in the morning prior to feeding to establish an average initial body weight (BW). Steers were blocked by BW into two weight blocks: light and heavy, stratified within BW, and assigned randomly to pens (n=16; 8 steers/pen). Pens were assigned randomly to one of two treatments (Control and Biochar; Table 1). Cattle were implanted with a Revalor-IS on d 1 and reimplanted with a Revalor-200 on d 79 (Merck Animal Heath, Summit, NJ). On d 190, cattle were harvested at Greater Omaha (Omaha, NE) recording liver abscesses and hot carcass weight (HCW) on day of slaughter. Carcass-adjusted final BW

was calculated using a common dressing percent of 63%. After a 48-hr chill, longissimus muscle (LM) area, 12th rib back fat and USDA marbling scores were recorded and yield grade were calculated using an assumed 2% KPH (kidney, pelvic and heart fat). At the conclusion of the experiment, dietary energy content was calculated using cattle performance and net energy system equations.

A 24-day step-up period was used to adapt cattle to the finishing diet. The adaption diet included 35% haylage and 10% corn stalks which was displaced with an equal blend of dry-rolled corn (DRC) and high moisture corn (HMC), increasing from 30% to 70% of the diet DM. The final base diet (CON) consisted of 35% DRC, 35% HMC, 5% corn stalks, 20% modified distillers grains plus solubles (MDGS), and 5% supplement. Biochar was incorporated into the diet on d 1 at 1.0% of diet DM and displaced both DRC and HMC at 0.5% each, with all other diet ingredient inclusions remaining constant.

The biochar was sourced from VGrid Energy Systems, Inc. (San Pablo, CA) and was made from pistachio shells using the processing method of gasification. Monthly samples were taken and sent to Control Laboratories (Watsonville, CA) for physical and chemical analysis. The biochar maintained a consistent DM, ranging from 90.4% to 92.5% (average of 91.6%). Carbon composition was 85% of DM, with a pH of 9.03, bulk density of 23.8 lb/ft^3, and a surface area of 217 m^2/g. Particle size distribution was categorized at <0.5mm (62.8%), 0.5–1mm (35.7%) and 1–2 mm (1.5%). Prior to trial initiation, VGrid Energy Systems established GRAS (Generally Recognized As Safe) status with Nebraska Department of Agriculture, as biochar is not approved by the FDA to be fed to cattle that will enter the food supply chain.

Four replicates (4 control and 4 biochar pens paired together) were assigned randomly and monitored for 16 consecutive weeks using the pen scale emissions barn (*2019 Nebraska Beef Cattle Report*, pp 60–62). Each replicate was measured 4 times in the barn (twice in each chamber). The barn uses a negative air pressure system equipped with LI-COR 7700 and LI-COR 7500 gas analyzers (LI-COR, Lincoln, NE) quantifying levels of CH_4 and CO_2. Each chamber is enclosed, ensuring no air emissions crossover. Within each replicate, one control and one biochar treatment were simultaneously monitored during a seven-day period. Cattle entered the emissions barn on d 1 at 0700 h each Wednesday, remained in the designated chamber pen, exited on d 5 at 0700 h on Monday and returned to their respective home pens. Days 1 to 5 were classified by time of feeding. One individual day was considered from time of feeding followed by the next days' time of feeding, approximately 24 hours. Day 6 captured manure contribution from the time cattle exited the barn to time of manure removal by a skid steer. Time after manure removal was assigned as d 7, until entry of the next cattle replicate, and was used to correct for baseline measurements.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) as a randomized block design. Pen was the experimental unit and block was included as a fixed effect. Emissions data were analyzed as a repeated measure using an unstructured covariance structure and significance was declared at a $P < 0.05$.

Table 2. Biochar supplementation effect on performance and greenhouse gas emissions in finishing steers

	Treatment[1]			
	Control	Biochar	*SEM*	*P*- value
Performance				
Initial BW, lb	725	724	0.97	0.52
Final BW, lb[2]	1506	1519	13.7	0.36
Dry Matter Intake, lb/d	25.1	25.3	0.28	0.61
Average Daily Gain, lb	4.11	4.18	0.049	0.31
Feed:Gain[3]	6.32	6.26	—	0.46
NEm, Mcal/lb	0.87	0.87	0.006	0.78
NEg, Mcal/lb	0.57	0.58	0.005	0.78
Carcass Characteristics				
HCW, lb	949	957	6.03	0.36
LM area, in^2	14.8	14.8	0.199	0.90
12th rib fat thickness, in	0.66	0.60	0.032	0.20
Marbling score[4]	527	514	11.8	0.45
Daily Emissions, on a per animal basis				
Dry Matter Intake, lb/d[5]	27.6	27.8	1.02	0.81
CH_4, g/day	141.4	144.2	5.80	0.76
CH_4, g/lb of DMI	5.9	5.9	0.38	0.88
CO_2, g/day	5245	5210	314.6	0.94
CO_2, g/lb of DMI	219.6	218.2	6.69	0.88

[1] Treatments included cattle fed a control diet or 1% biochar replacing corn in the diet.

[2] Final BW calculated from Hot Carcass Weight (HCW) with a standard 63% dress.

[3] Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[4] Marbling score 300 = slight, 400 = Small, 500 = Modest, 600 = Moderate

[5] Dry matter intake (DMI) used to calculate weekly average emissions during a 5-day collection period in the emission barn

Results

Cattle performance and carcass characteristics were not statistically different between treatments ($P \geq 0.20$; Table 2). Across both treatments cattle consumed 25.2 lb (DM basis) of feed each day ($P = 0.61$) while gaining 4.15 lb/d ($P = 0.31$). Cattle performed with an average feed conversion of 6.29 ($P = 0.46$). Dietary energy concentration was not different between treatments ($P = 0.78$). Hot carcass weight of cattle was not impacted by treatment, averaging 953 lb ($P = 0.36$).

For both treatments, the average methane production was 142.8 g/d and 5.9 g of CH_4/lb of DMI. Carbon dioxide recorded averaged 5,228 g/d and 218.9 g/lb of DMI. Overall, emissions of CH_4 and CO_2 did not differ among cattle fed a diet with or without biochar (Table 2; $P \geq 0.76$).

Conclusion

Biochar sourced from pistachio shells included at 1% of diet DM did not show any advantages for reducing CH_4 and CO_2 emissions, but did not adversely impact cattle health, animal performance or carcass traits. Previous *in vivo* biochar research has shown inconsistent results on reducing emission levels, as there are many factors of biochar to be considered: processing method, source, physical and chemical composition. After multiple studies conducted utilizing the two-pen scale emission barn at UNL, no specific diet or type of biochar combination has yet proven to reduce CH_4 or CO_2 from finishing beef cattle.

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Ponderosa Pine Wood Biochar used as an Emissions Reduction Strategy in a Finishing Beef Cattle Diet

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Summary with Implications

A finishing feedlot experiment was conducted to evaluate the impact of feeding biochar on methane and carbon dioxide production, performance, and carcass characteristics in beef cattle. Two dietary treatments were evaluated; 0 or 1% biochar in a high concentrate diet comprised of dry-rolled corn, high moisture corn, Sweet Bran, and corn silage. Ponderosa pine wood biochar was added into the diet at 1% dry-matter displacing a 1% dry-matter blend of corn. Cattle were monitored using a calorimetry emissions barn to capture methane and carbon dioxide production. Emissions production, performance and carcass characteristics did not differ between cattle fed a control diet without biochar or cattle fed a diet containing biochar.

Introduction

The agricultural sector has been under scrutiny and challenged to reduce atmospheric gases such as methane (CH_4) and carbon dioxide (CO_2), specifically from enteric methane in cattle. Intake and diet quality are the main determinants of methane emissions. Enteric fermentation of feeds occurs within the rumen, naturally producing CH_4 through eructation as well as respired CO_2, but CH_4 losses are deemed unfavorable to the animal as this process comes at an energetic expense. Reduction strategies have been evaluated by using different dietary compositions and feed additive combinations. A product called biochar has been a proposed feed additive for its methane reduction potential properties. Biochar's mechanism is not fully understood, but theories suggest its large surface area and porous nature are favorable in promoting biofilm growth within the rumen resulting in increased feed degradation and reduced production of methane. The objective of this study was to evaluate the effect of biochar supplemented at 1% of diet dry matter (DM) on methane and carbon dioxide production, cattle performance, and carcass characteristics.

Table 1. Diet composition (% of DM) fed to finishing steers

Ingredient, %	Control	Biochar
Dry-rolled corn	20	19.5
High moisture corn	20	19.5
Sweet Bran	40	40
Corn silage	15	15
Biochar—wood[1]	-	1
Supplement	5	5
Fine ground corn	2.8825	2.8825
Limestone	1.60	1.60
Tallow	0.125	0.125
Salt	0.30	0.30
Trace mineral premix	0.05	0.05
Vitamin ADE	0.015	0.015
Rumensin-90[2]	0.0165	0.0165
Tylan-40[3]	0.011	0.011

[1]Displaced corn by 1% of diet DM

[2]Supplement formulated to provide 30 g/ton of Rumensin® (Elanco Animal Health, DM basis)

[3]Supplement formulated to provide 8.8 g/ton of Tylan® (Elanco Animal Health, DM basis)

Procedure

A 141 d experiment was conducted at the Eastern Nebraska Research, Extension and Education Center (ENREEC) near Mead, Nebraska. Prior to experiment initiation, cattle were limit-fed a common diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) on a DM basis at 2% of body weight (BW) for 5 d to equalize gut fill. One hundred twenty-eight steers were utilized in a randomized block design. To establish an average initial body weight (BW = 851 lb; SD ± 41 lb), steers were weighed on two consecutive days in the morning prior to feeding. Steers were blocked by BW into two weight blocks: light and heavy, stratified within BW, and assigned randomly to pens (n=16; 8 steers/pen). Pens were assigned randomly to one of two treatments (Control and Biochar; Table 1). Cattle were implanted with a Revalor-XS on d -1 (Merck Animal Heath, Summit, NJ). On d 141, cattle were harvested at Greater Omaha (Omaha, NE) recording hot carcass weight (HCW) and liver abscess scores on day of slaughter. Carcass-adjusted final BW was calculated using a common dressing percent of 63%. After a 48-hr chill, longissimus muscle (LM) area, 12th rib back fat, USDA marbling scores, and yield grade were measured and calculated. At the conclusion of the experiment, dietary energy content was calculated using cattle performance and net energy system equations.

A 24 d adaption period was utilized with corn silage inclusion decreasing in the diet and high moisture and dry rolled corn blend inclusion increasing while Sweet Bran and supplement remained constant.

Table 2. Biochar supplementation effect on performance and greenhouse gas emissions in finishing steers

	Treatment[1]			
	Control	Biochar	*SEM*	*P*- value
Performance				
Initial BW, lb	851	852	0.78	0.39
Final BW, lb[2]	1520	1511	9.36	0.47
Dry Matter Intake, lb/d	30.7	30.8	0.36	0.43
Average Daily Gain, lb	4.75	4.68	0.065	0.36
Feed:Gain[3]	6.43	6.55	—	0.21
NEm, Mcal/lb	0.83	0.82	0.006	0.29
NEg, Mcal/lb	0.54	0.53	0.006	0.29
Carcass Characteristics				
HCW, lb	958	952	5.90	0.47
LM area, in^2	14.6	14.6	0.223	0.84
12th rib fat thickness, in	0.69	0.66	0.026	0.45
Marbling score[4]	638	653	17.4	0.68
Daily Emissions, on a per animal basis				
Dry Matter Intake, lb/d[5]	27.2	27.4	1.02	0.91
CH_4, g/day	191.8	193.1	3.09	0.78
CH_4, g/lb of DMI	7.2	7.1	0.34	0.84
CO_2, g/day	4676	4213	461.7	0.50
CO_2, g/lb of DMI	174.3	154.5	20.55	0.52

[1] Treatments included cattle fed a control diet or 1% biochar replacing corn in the diet.

[2] Final BW calculated from Hot Carcass Weight (HCW) with a standard 63% dress.

[3]Analyzed as Gain:Feed, the reciprocal of Feed:Gain

[4] Marbling score 300 = slight, 400 = Small, 500 = Modest, 600 = Moderate

[5] Dry matter intake (DMI) used to calculate weekly average emissions during a 5-day collection period in the emission barn

The biochar was provided by Vital Ag (Bellwood, NE), sourced from ponderosa pine wood and made using the pyrolysis processing method. Monthly samples were taken, composited, and sent to Control Laboratories (Watsonville, CA) for physical and chemical analysis. The biochar maintained a consistent DM, ranging from 92% to 92.5%. Carbon composition was 74% of DM, a pH of 6.83, bulk density of 10.7 lb/ft^3, and a surface area of 180.5 m^2/g. Particle size distribution was categorized at <0.5mm (0.4%), 0.5–1mm (0.35%), 1–2 mm (4.2%), 2–4mm (23.25%), 4–8mm (47.85%) and 8–16mm (8.6%). Prior to experiment initiation, a food use authorization was granted which allowed for slaughter of these experimental cattle. Biochar fed to cattle intended for human consumption is not approved by the FDA.

Four replicates (4 control and 4 biochar pens paired together) were assigned randomly and monitored for 8 weeks using the pen scale emissions barn (*2019 Nebraska Beef Cattle Report*, pp. 60–62). Each replicate was monitored at two timepoints (once in each chamber), each lasting for 7 consecutive days. The barn uses a negative air pressure system equipped with LI-COR 7700 and LI-COR 7500 gas analyzers (LI-COR, Lincoln, NE) quantifying levels of CH_4 and CO_2. Each chamber is enclosed ensuring no air emissions crossover. Within each replicate, one control and one biochar treatment were simultaneously monitored during a seven-day period. Cattle entered the emissions barn on d 1 at 0700 h each Wednesday, remained in the designated chamber pen, exited on d 5 at 0700 h on Monday, and returned to their respective home pens. Days 1 to 5 were classified by time of feeding. One individual day was considered from time of feeding followed by the next days' time of feeding, approximately 24 hours. Day 6 consisted of manure contribution to CH_4 and CO_2 emissions, from the time cattle exited the barn to time of manure removal by a skid steer. Time after manure removal was assigned as d 7, until entry of the next cattle replicate and was used to correct for baseline measurements.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) as a randomized block design. Pen was the experimental unit and block was a fixed effect. Emissions data were analyzed as a repeated measure using a compound symmetry covariance structure and significance was declared at a $P < 0.05$.

Results

Cattle performance and carcass characteristics observed were not different between cattle fed the control or biochar finishing diet ($P \geq 0.21$; Table 2). On average cattle consumed 30.8 lb of feed each day ($P = 0.43$) while gaining 4.72 lb/d ($P = 0.36$) and a feed conversion of 6.49 ($P = 0.21$). The dietary energy concentration was not different between the control and biochar diet ($P = 0.29$). Cattle HCW was not affected by treatment, averaging 955 lb ($P = 0.47$).

The average methane captured for both treatments was 192.5 g/d, and 7.15 g/lb of DMI.

Carbon dioxide recorded averaged 4,444 g/d and 164 g/lb of DMI for both biochar and control fed cattle. Overall, emissions of CH_4 and CO_2 did not differ between cattle fed a diet with biochar or without biochar (Table 2; $P \geq 0.50$).

Conclusion

The addition of ponderosa pine wood biochar at 1% of diet DM did not reduce emissions of CH_4 or CO_2 from cattle. Performance and carcass characteristics were not different between cattle fed a high concentrate diet with or without biochar. Many factors are attributed to emissions reduction results such as cattle genetics, source and type of biochar, and diet quality. Research experiments using a low-quality forage growing diet (*2021 Nebraska Beef Cattle Report*, pp. 31–32), and high concentrate finishing diets (*2022 Nebraska Beef Cattle Report*, pp. 77–78; *2023 Nebraska Beef Cattle Report*, pp. 75-77) using the UNL pen-scale respiration calorimetry barn have demonstrated consistent results,

in that feeding biochar does not reduce greenhouse gas emissions emitted by beef cattle.

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Greenhouse Gas Emissions from Two Beef Systems from Birth to Slaughter in Eastern Nebraska

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Summary with Implications

Methane emissions from growing and finishing calves born into a spring calving, conventional cow system or a summer calving, partially-confined cow system were compared. Cows fed a restricted diet of corn-byproduct and grain residues in confinement produced less methane and carbon dioxide per day compared to cows grazing pasture or cover crop. Calves weaned from the confinement-based production system were smaller at weaning and compensated with greater gain during the growing phase. More days on feed in the finishing phase were needed for the calves from the confinement system to reach same backfat thickness. Over the entire growing and finishing phases, calves from the confinement-based system produced more total methane and methane per lb of carcass weight. Carbon sequestered into brome pasture and oat forage biomass was measured. Total measured emissions from all stages of beef production were combined with modeled emissions from soil and manure. Conventional cow-calf production grazing perennial cool season grasses sequestered enough carbon to offset 138% of all carbon emissions from gestation, lactation, growing and finishing stages. Annual forages grazed in the partial confinement system offset 70% of total emissions from the system. Minimizing emissions and maximizing sequestration can make beef production climate neutral or better, depending on management practices used.

Introduction

It is a common perception that agriculture, and especially the beef livestock sector, is an emitter of greenhouse gases (GHG) and contributor to climate change. Both carbon sequestration in grazing lands and global warming potential (GWP) of methane (CH_4) need to be accounted for when assessing the impact of beef cattle. Methane has traditionally been assigned a GWP of 23 to 82 times more potent than CO_2 depending on the degradation rate of CH_4 used. New GHG accounting methods simultaneously account for both production of CH_4 and natural atmospheric breakdown of CH_4 (9 to 12 years compared to 1000 years for CO_2). These accounting methods regard CH_4 as having only 4 times the potency of CO_2. Multiplying CH_4 by GWP is used to express CH_4 in CO_2 equivalents (CO_2e).

Open-air micrometeorological techniques have been implemented to measure carbon sequestration in ecosystems worldwide. Eddy covariance simultaneously measures the C flux into and out of a given area. This technique can be used to better understand C flux from beef production, taking into account emissions from enteric fermentation and respiration as well as sequestration.

The objective of this experiment was to measure GHG production within two beef production systems from conception to slaughter and express those emissions per unit of beef produced. In addition, sequestration of carbon and offsets of GHG within each system were measured. This included assessing CO_2e from CH_4 using 2 different GWP values.

Procedure

The GHG emissions from cattle in two cow-calf systems were evaluated. At the onset of the experiment, 160 cows were assigned randomly to one of 2 production systems, conventional (CONV) and alternative (ALT). Cow age was equally represented in both systems. In each system, 4 groups of cows (n=20) were raised under set conditions for 2 consecutive years, and post-weaning practices remained the same for all calves (steers and heifers). The CONV system was a pasture-based system. Cow-calf pairs grazed bromegrass pastures from May 1 to October 26, calved between April 15 and June 15 and weaned October 15 when calves were approximately 168 days of age. After weaning, cows grazed corn residue from October 27 to March 15, then returned to grass pastures and were fed grass hay until forage growth was adequate for grazing. The ALT system was an intensive, feedlot-based system during the summer and grazing during the fall and winter. Cows entered the feedlot on March 15 and were limit-fed from March 15 until calving which occurred July 15 to September 15. Cow feed intakes were adjusted to meet gestation and lactation needs. After calving, cow-calf pairs grazed secondary annual forage (oats) from October 15 to January 15, when calves were weaned. Following grazing cows grazed corn residue from January 16 to March 15.

A pen chamber was used to measure GHG emissions (*2021 Nebraska Beef Cattle Report*, pp. 79–82) from cows and calves (nursing, growing and finishing). Cattle were in the chambers for 5 days. Diets fed in the pen chamber are shown in Tables 1 and 2. During year 3 of the study, nursing calves from the ALT system remained in the pen chamber for 6 hours after the cows were sent back to the home pen. Calf CO_2 and CH_4 measured during this period in combination with some data in the literature were used to develop a regression of CO_2 and CH_4 production relative to calf body weight. The calf contribution was then subtracted from the total flux to determine the flux from only cows in grazing scenarios.

Table 1. Composition of diets (DM basis) fed to cattle during growing and finishing phases.

	Growing	Finishing	
Ingredient, % DM	Years 1 and 2	Year 1	Year 2
Dry rolled corn	30	34	
High moisture corn		34	41
Sweet Bran			40
Modified distillers grains	30	20	
Corn silage			15
Grass hay	35	7	
Supplement	5	5	4
Fine ground corn	2.52	2.29	1.878
Limestone	1.98	1.69	1.63
Tallow	0.13	0.13	0.10
Urea	0	0.5	0
Salt	0.30	0.30	0.30
Beef trace mineral	0.05	0.05	0.05
Vitamin ADE premix	0.015	0.015	0.015
Rumensin 90 premix	0.012	0.017	0.017
Tylan 40 premix	0	0.011	0.010

Table 2. Ingredient composition of confinement diet fed to alternative cow-calf system by year during pen-scale GHG measurement[1]

	Gestation			Lactation		
Ingredient, %	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
MDGS[2]	55.00	55.00	35.00	55.00	55.00	35.00
Corn silage			40.00			
Forage Silage						21.31
Wheat straw	40.00	40.00	20.00	41.34		40.00
Oat straw					41.34	
Supplement	5.00	5.00	5.00	3.66	3.66	3.69
Fine ground corn	2.47	2.49	2.49	1.79	1.80	1.83
Trace mineral salt	—	1.79	1.79	—	1.31	1.31
Limestone	1.98	0.57	0.57	1.45	0.42	0.42
Salt	0.30	—		0.22	—	
Tallow	0.13	0.13	0.13	0.09	0.09	0.09
Beef trace mineral	0.10	—		0.07	—	
Insect growth regulator	—	—		0.02	0.02	0.02
Vitamin A-D-E premix	0.02	0.02	0.02	0.01	0.01	0.01
Rumensin 90 premix	0.01	0.02	0.02	0.01	0.01	0.01
Nutrient Composition						
DM, %	66.88	66.88	55.05	66.75	67.29	63.78
TDN, % of DM	63.66	64.78	69.62	63.66	64.78	66.82
Fat, % of OM	6.29	6.24	5.26	6.29	6.24	4.27
Protein % of OM	18.3	18.1	14.7	18.3	18.1	14.4

[1] All values represented on a DM basis unless noted

[2] Modified distillers grains plus solubles

For measurements of GHG in grazed scenarios (bromegrass pasture, forage oats, and corn residue) eddy covariance techniques were used. To measure CO_2 production, an open path laser was used (LI-7500DS Open-Path CO_2 /H_2O Analyzer; LI-COR Biosciences, Lincoln, NE). For N_2O and CH_4, a closed-path analyzer was also installed (N_2O/CO Analyzer Los Gatos Research San Jose, CA). Eddy covariance uses the variation in upwind turbulence generated by wind dynamics with surface of the earth. Concentrations of CO_2 and CH_4 are measured 10 times per second. The covariance of that data over time is used to calculate the flux toward or away from the surface. Fluxes will change depending on the biomass growth and other sources and sinks in the ecosystem measured. Cattle are moving point sources and their locations must be tracked to determine if they are in the upwind area known as the fetch.

To track individual animal movements, GPS loggers (igotU GT-600; Tenergy) were given to each cow, bull and calf in the cow group being measured. The GPS collars were removed every 4 to 6 weeks to download the data and recharge the batteries. The spatial distribution of the livestock was averaged over a 30-minute duration and a gap-filling procedure was used to calculate the location of the animal based on the previous and subsequent GPS coordinates in the event of missing data. The flux per animal was determined from the regression of animals in the footprint relative to size of the flux.

Manure emissions (CH_4, CO_2 and nitrous oxide, N_2O) and fossil fuel use were not directly measured. Work from other life-cycle assessments of beef production estimated 5.84 lb CO_2e per lb of hot carcass weight (HCW) from manure and soil GHG and CO_2 from combustion of fossil fuels used in beef production. Modeled emissions were combined with measured CH_4 and CO_2 from CONV and ALT to determine total GHG to be sequestered from the production system. Cattle in CONV and ALT were slaughtered at equal backfat thickness, but groups had different numbers of days on feed and feed intake.

Production of CO_2 and CH_4 (grams/lb DMI) from pen-chamber data were

Table 3. Observed CH4 and CO2 production per animal in pasture-based (CONV) or partial-confinement (ALT) beef productions systems.

		CH_4			CO_2		
	DMI, lb	Per lb. DMI, g	Per animal daily, g	Total per animal, lb	Per lb. DMI, g	Per animal daily, g	Total per animal, lb
Cow only							
Corn Residue	19.7	9.7	191.9	12.2	375.6	7399.7	469.9
Brome Pasture	31.0	9.6	297.8	24.0	532.8	16500.0	1332.2
Cover crop	51.2	6.0	309.2	11.6	305.4	15625.0	588.3
Gestating Cow (Drylot)	15.3	9.0	137.0	7.6	389.7	5945.0	331.7
Lactating Cow (Drylot)	20.2	7.4	149.4	6.9	254.7	5131.9	237.4
Growing Calf							
CONV	19.6	6.2	121.8	36.8	252.4	4948.0	1498.0
ALT	19.1	6.4	122.9	35.0	246.8	4713.0	1330.0
Finishing Calf							
CONV	23.3	5.4	125.0	40.6	323.9	7551.0	2485.0
ALT	23.8	6.1	145.2	59.5	298.4	7111.0	2852.0
Calf contribution on cow							
Pen chamber			25.6			1892.2	
Pasture			51.6			2740.7	
Cover Crop			54.6			2856.0	

analyzed using PROC MIXED, with day in barn as the repeated measure. Because intake was not measured in grazing scenarios, emissions were expressed per animal daily instead of unit of DMI. The 95% confidence interval around the mean was calculated for eddy covariance data with minimum and maximum values reported. The difference in min and max for each system was used as an indication of numerical vs statistical difference.

Results

Emissions—CH4

Results of pen chamber and open-air measurements are presented in Table 3. For cows grazing corn residue CH_4 production was 204 ± 25.8 g per cow daily compared to 155 ± 14.6 g from gestating cows in ALT system. During lactation ALT cow-calf pairs produced 175 g ± 16.8 g compared to CONV pairs grazing brome pasture which produced 322.76 ± 50.7, 404.81 ± 113.7 and 322.0 ± 56.9 g during early, mid, and late grazing periods respectively. ALT cows grazing cover crops produced 357.23 g ± 43.1 per pair per day.

Comparison of systems GHG production during gestation and lactation phases are presented in Table 4. Overall, less CH_4 was observed during gestation since CONV cows were producing 204 g per animal per day grazing residue and ALT cows were only producing 155 g per animal per day when being fed in the drylot. Considering the number of days in each environment, CONV and ALT cows produced 84.4 ± 13.9 and 62.4 ± 7.4 lb CH_4 over the gestation period. During lactation cows produced 136 for conv ± 20.6 and 105 ± 11.7 lb CH_4 for CONV and ALT, respectively.

During the growing phase (Table 5) no differences in DMI were observed, but compensatory gain in ALT calves resulted in greater ADG and improved F:G ($P < 0.01$; *2021 Nebraska Beef Cattle Report*, pp. 79–82). No differences in CH_4 per day or lb DMI were observed, but CONV calves produced more ($P < 0.01$) CH_4 per lb ADG (53.7 vs 44.8 g per lb ADG, respectively). There were no differences in total CH_4 per hd during growing. In the finishing phase many of the opposite trends observed in the growing phase were observed. During finishing CONV calves had greater ADG and no differences in DMI, resulting in improved F:G. No differences in CH_4 per lb DMI but greater ($P = 0.02$) CH_4 per lb ADG in ALT (43.2 vs 31.7 g per lb ADG, respectively). During the finishing phase ALT calves were fed 35 days longer than CONV calves to achieve similar backfat. The advantage in emissions from the gestation phase was lost during the finishing phase since ALT calves had greater total CO_2e (3090 ± 556 vs 2647 ± 291).

Emissions—CO2

During gestation carbon dioxide production was greater during CONV system because CO_2 production per animal per day was 7,400 g on corn residue and only 5,945 g when ALT cows were limit-fed in a drylot. Production of CO_2 was high in both pasture grazing (16,500 g CO_2 per cow per day) and cover crop (15625 g CO_2 per cow per day) grazing likely due to high intakes by lactating cows.

Daily production of CO_2 during growing (4948 and 4713 g per animal per day for CONV and ALT, respectively) and finishing (7551 and 7111 g per animal per day for CONV and ALT, respectively) was not statistically different between CONV

Table 4. Production of CH4 and CO2 in pasture-based (CONV) or partial-confinement (ALT) production systems during gestation, and lactation.

	CONV			ALT		
	Mean	Lower	Upper	Mean	Lower	Upper
Gestation						
DMI, lb	21.0	14.1	28.8	16.7	13.7	20.1
Days	188.0	188.0	188.0	183.0	183.0	183.0
CH_4						
CH_4 per lb DMI, g	9.7	12.1	8.8	9.3	10.0	8.6
CH_4 per hd per day, g	203.5	170.1	253.2	154.7	136.4	172.6
Total CH_4, lb	84.4	70.5	104.9	62.4	55.0	69.6
CO_2						
CO_2 per lb DMI, g	353.6	380.2	250.2	384.3	389.2	327.5
CO_2 per hd per day, g	7436.5	5349.2	7204.7	6414.0	5322.9	6566.5
Total CO_2, lb	3082.2	2217.1	2986.1	2587.7	2147.5	2649.2
Global warming potential						
CO_2e from CH_4, lb 4x	337.4	282.1	419.7	249.6	220.2	278.5
CO_2e from CH_4, lb 23x	1940.2	1621.9	2413.3	1435.3	1266.1	1601.4
CO2e per hd per d, lb	3.4	2.5	3.4	2.8	2.4	2.9
Lactation						
DMI, lb	31.0	15.7	50.0	34.5	23.6	54.2
Days	177.0	177.0	177.0	182.0	182.0	182.0
CH_4						
CH_4 per lb DMI, g	11.3	17.7	8.4	7.6	9.9	5.4
CH_4 per hd per day, g	349.5	278.8	420.1	262.2	233.2	291.5
Total CH_4, lb	136.4	108.8	163.9	105.2	93.6	117.0
CO_2						
CO_2 per lb DMI, g	350.8	173.4	647.7	333.0	220.9	536.3
CO_2 per hd per day, g	19240.7	14919.7	26470.7	12311.8	10618.5	14005.6
Total CO_2, lb	7508.1	5821.9	10329.4	4940.0	4260.6	5619.6
Global warming potential						
CO_2e from CH_4, lb 4x	545.6	435.2	655.6	420.8	374.4	468.0
CO_2e from CH_4, lb 23x	3136.4	2502.3	3770.6	2419.3	2152.2	2689.9
CO2e per hd per d, lb	8.1	6.3	11.0	5.4	4.6	6.1

and ALT. Total CO_2 production was greater in ALT calves since they had greater DOF ($P = 0.02$)

Animal performance in the two systems had a profound effect on emissions. Calves in the ALT system were 99 lb lighter at weaning. This weight difference was maintained through the end of the finishing phase, requiring calves from the ALT to be fed 35 days longer to achieve similar weight and backfat. Total production of CO_2e from the CONV system was greater (15,795 ± 2522 vs 12,758 ± 1715 lb CO_2e from CO_2 and CH_4 for CONV and ALT, respectively) and production per unit of beef produced (22.9 ± 3.5 and 19.1 ± 2.6 lb CO2e per lb HCW). Controlling intake by delivering harvested feed when cows were in drylot resulted in less over all CH_4 and CO_2 across the entire production system even though ALT calves were fed an additional 35 days to reach market weight.

While DMI is reported, values for DMI during open-air measurements of grazing cattle were not directly measured. Intake was predicted in these scenarios based on observed emissions and a GHG emissions model. Feed intake during all drylot scenarios was measured.

Carbon Balance

Cows in the CONV system grazed smooth bromegrass for, on average, 179 days with 3 acres per cow-calf pair. Cows in the ALT system grazed oat forage for 85 days with 2.6 acres per cow-calf pair. The carbon sequestered during these two periods was compared to all emissions from

Table 5. Production of CH4 and CO2 in pasture-based (CONV) or partial-confinement (ALT) production systems during growing and finishing phases.

	CONV			ALT		
Growing	Mean	Lower	Upper	Mean	Lower	Upper
DMI, lb	19.6	19.1	20.2	19.1	18.4	19.7
Days	183.0	183.0	183.0	183.0	183.0	183.0
CH4						
CH_4 per lb DMI, g	7.3	6.6	8.0	7.1	6.8	7.0
CH_4 per hd per day, g	121.8	109.7	134.1	122.9	107.0	138.7
Total CH_4, lb	36.8	33.4	40.2	35.0	32.4	37.6
CO_2						
CO_2 per lb DMI, g	297.8	262.6	331.0	271.9	246.6	297.2
CO_2 per hd per day, g	4948.0	4430.0	5466.0	4713.0	3893.0	5534.0
Total CO_2, lb	1498.0	1328.5	1668.0	1330.0	1213.9	1382.5
Global warming potential						
CO_2e from CH_4, lb 4x CO2	147.2	133.4	160.9	140.0	129.5	150.6
CO_2e from CH_4, lb 23x CO2	846.2	767.2	925.4	805.0	744.5	865.7
CO2e per hd per d, lb	1.6	1.5	1.8	1.5	1.3	1.5
CO_2e per lb HCW	5.1	4.6	5.7	4.8	4.4	5.1
Finishing						
DMI, lb	23.3	22.3	24.3	23.8	23.1	24.5
Days	148.0	148.0	148.0	183.0	183.0	183.0
CH4						
CH_4 per lb DMI, g	5.3	4.6	6.1	6.1	4.5	7.7
CH_4 per hd per day, g	125.0	105.0	145.0	145.2	104.7	185.7
Total CH_4, lb	40.6	35.7	45.3	59.5	39.5	79.6
CO_2						
CO_2 per lb DMI, g	325.2	297.1	353.2	300.3	242.1	358.4
CO_2 per hd per day, g	7551.0	7151.0	7953.0	7111.0	5892.0	8330.0
Total CO_2, lb	2485.0	2213.4	2740.3	2852.0	2376.6	3336.3
Global warming potential						
CO_2e from CH_4, lb 4x CO2	162.4	142.7	181.4	238.0	157.9	318.3
CO_2e from CH_4, lb 23x CO2	933.8	820.3	1042.9	1368.5	907.6	1830.5
CO2e per hd per d, lb	2.6	2.4	2.9	3.1	2.5	3.7
CO_2e per lb HCW	8.2	7.3	9.1	10.2	8.4	12.1
HCW per cow exposed, lb	707.7	707.7	707.7	668.4	668.4	668.4

gestation, lactation, growing and finishing phases (Table 6). Carbon sequestration during bromegrass pasture and oat cover crop was 2,524 and 1,228 lb C per acre per year or 7,523 and 3,255 lb C per cow for CONV and ALT, respectively. When considering GWP of CH_4 as 23 and N_2O as 298, total emissions from the CONV system were 7,388 and 6,295 lb CO_2e per cow for CONV and ALT respectively. This resulted in a balance of 135 and -3040 lb C for CONV and ALT, respectively. Using the traditional method of GHG accounting, the CONV system is C neutral and the ALT system is a source of emissions. When considering GWP of CH_4 as 4 and N_2O as 234, this changes the production, but carbon sequestration remains unchanged. The balance using these new values for GWP result in a balance of 2096 and -1,288 lb C per cow for CONV and ALT, respectively. This means the CONV system would sequester 138% of emissions from the entire production system. Sequestration from grazing oat forage sequestered 70% of all emissions from the ALT system. This was reduced to 103 and 52% for CONV and ALT when using 23 and 298 for GWP of CH_4 and N_2O, respectively. The positive carbon balance in the CONV system can likely be attributed to increases in soil carbon and root growth.

Conclusion

The partial-confinement system resulted in less over all emissions of CO_2 and CH_4. Calves from this system were smaller at weaning and required more days on feed to achieve market weight. The pasture-based production system produced more emissions of CO_2 and CH_4 but more carbon was sequestered from the annual forages grazed in that system. Cows from this system were either carbon neutral or a carbon sink depending on the GHG accounting metrics

Table 6 Carbon balance of pasture based (CONV) or partial confinement (ALT) beef production system from emissions and carbon sequestration

Net CO_2e after C sequestration[1]	CONV			ALT		
	Mean	Lower	Upper	Mean	Lower	Upper
Emissions, lb per lb HCW						
CO_2	20.6	17.4	25.4	17.5	15.2	19.8
CH_4 (23x CO2)	9.7	8.1	11.5	9.0	7.6	10.5
CH_4 (4x $CO_{2)}$	1.7	1.4	2.0	1.6	1.3	1.8
Modeled N_2O emissions (298x CO_2)	8.0			8.0		
Modeled N_2O emissions (234x CO_2)	5.8			5.8		
Total						
CO_2e per lb HCW (23x CO_2)	38.3	33.4	44.9	34.5	30.8	38.2
CO_2e per lb HCW (4x CO_2)	28.1	24.6	33.3	24.9	22.4	27.4
	CH_4 23x CO_2 and N_2O 298 x CO_2					
Production						
C per cow exposed lb	7388	6450	8671	6295	5610	6966
Sequestration						
C per cow exposed, lb	7523	6429	8616	3255	2241	4270
Balance						
C per cow exposed, lb	135	-21	-55	-3040	-3369	-2696
	CH_4 4x CO_2 and N_2O 234 x CO_2					
Production						
C per cow exposed lb	5426	4747	6418	4544	4074	4998
Sequestration						
C per cow exposed, lb	7523	6429	8616	3255	2241	4270
Balance						
C per cow exposed, lb	2096	1682	2198	-1288	-1834	-728

used. Traditional research in beef production considers only emissions. The data for these grazing situations indicate that soil carbon uptake is greater than all emissions from beef production. Additional research is needed to measure carbon sequestration over multiple years, varying types of forages and stocking densities to determine how much carbon can be sequestered within the beef production system.

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Analysis of Spoilage Bacteria Present in Vacuum Packaged Chilled Beef Treated with Organic Acids

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Summary with Implications

Preventing the spoilage of fresh, chilled beef is crucial for maintaining market value. Since organic acids are regularly used in the beef industry for pathogen control, their ability to improve the shelf life of fresh, chilled beef was evaluated. Fresh, chilled beef was individually treated with 4.5% lactic acid, 2.5% Beefxide®, or 380 ppm peroxyacetic acid. After storage, Lactococcus, a genus of lactic acid bacteria, became the most common spoilage organism across all treatment and control samples. Organic acid treatments were not able to slow the growth of this genus and may not be an effective method to control spoilage when lactic acid bacteria are the dominant spoilage organism present.

Introduction

In 2020, the U.S. beef industry exported 1.2 million tons of beef valued at over $7 billion. Fresh, chilled beef from the U.S. is considered a premium product, and ensuring that these products arrive at their export destination without the negative effects of bacterial spoilage is crucial for maintaining their value. Spoilage bacteria can create a variety of off-aromas, textures, and colors that make the meat undesirable for the consumer. Often, organic acids like lactic acid are used in beef processing facilities to decrease the presence of *E. coli* O157:H7, but these compounds are also able to slow the growth of spoilage bacteria that may be present on the meat. An experiment was conducted to determine the impact of different organic acids on the prevalence of spoilage bacteria during extended storage of vacuum packaged, raw beef.

Procedure

Beef chuck rolls (N = 24) from two processing facilities were obtained on two separate days of production. Chuck rolls from each facility and day of production were processed separately seven days post mortem. Each chuck roll was cut in half and each half was assigned to a treatment (4.5% lactic acid, 2.5% Beefxide®, 380 ppm peroxyacetic acid, or a no-treatment control), and then halves were cut into at least six smaller pieces each weighing approximately two pounds. The pieces were submerged into the assigned organic acid treatment (73 °F) for 15 seconds, drip-dried for two minutes, and individually vacuum sealed. Samples were stored at 37 °F for 112 days in a dark cooler. Every 28 days starting on the day of organic acid treatment (day 0) and ending on day 112, plate counts, 16S sequencing, surface color, and surface pH were evaluated. For plate counts and sequencing, 100 g was cut from the surface of each piece and homogenized with 100 mL of buffered peptone water. Homogenate was plated in duplicate onto brain heart infusion agar for aerobic, anaerobic, and psychrotrophic plate counts; deMan Rogosa Sharpe agar for lactic acid bacteria; and cephaloridine fucidin cetrimide agar for *Pseudomonas*. DNA was also extracted from homogenates and then amplified targeting the V4 region of the 16S rRNA bacterial gene with polymerase chain reaction. Purified V4 16S gene segments were sequenced with the Illumina MiSeq and analyzed using R. L*, a*, b*, and pH were measured on the surfaces of each two-pound piece after removing it from the vacuum package. The experiment was conducted in two independent replications with one day of production from each facility included in each replication. Data for microbial plate counts, sequencing alpha diversity, color, and pH were analyzed as an incomplete block design with 2 locations, 4 treatments, and 5 sampling days in SAS 9.4. Sequencing beta diversity was analyzed by conducting a principal coordinate analysis and a PERMANOVA in R with treatment, location, sampling day, block, and a treatment: day interaction included in the model. Samples stored for 28 days from the second location were not evaluated due to a COVID related laboratory closure that prevented sampling.

Results

Treatment of raw beef with Beefxide®, lactic acid, and peroxyacetic acid resulted in spoilage by lactic acid bacteria during vacuum packaged, refrigerated storage. Meat spoilage is typically indicated by bacterial counts greater than 7 $\log_{10}$ and a decrease in alpha diversity (diversity of bacteria within a sample). Concentrations of anerobic and lactic acid bacteria plate counts approached 7 $\log_{10}$ after 56 days of storage (Figure 1), and alpha diversity decreased from day 0 to day 28. The dominance of lactic acid bacteria is also shown by the relative abundance of 16S sequences. *Lactococcus* are present in a relatively small proportion on day 0 and then become the most abundant genus throughout the remainder of storage across all treatment and control samples. A trend in the *Pseudomonas* plate counts ($P = 0.07$) was seen where lactic acid and Beefxide® treatments had lower *Pseudomonas* concentrations than the control group (Figure 1). This pattern was also observed in the 16S abundances on days 56, 84, and 112 where the control and peroxyacetic acid treatment groups had slightly higher abundance of *Pseudomonas* compared to the lactic acid and Beefxide® treatments. This suggests that organic acid treatments containing lactic acid may aid in slowing the growth of *Pseudomonas*. However, clustering in the principal coordinate analysis showed that even though treatment was significant ($P < 0.01$), the primary grouping of samples is attributed to length of storage. The difference in alpha diversity between treatments was

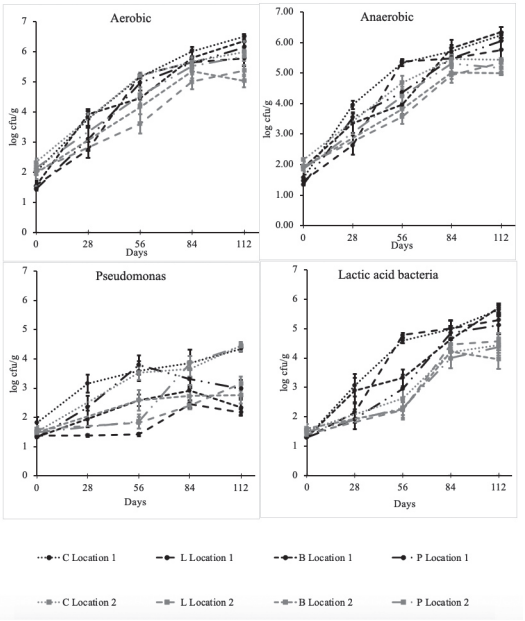

Fig. 1. Concentration of aerobic, anaerobic, *Pseudomonas*, and lactic acid bacteria (log_{10} cfu/g) during cold storage. Error bars represent standard error. C = control. L = Lactic acid B = Beefxide®. P = Peroxyacetic acid.

also not significant (Observed $P = 0.30$, Chao1 $P = 0.39$) further indicating that the bacterial composition of treated samples was not different than the untreated control samples. Both the principal coordinate analysis and alpha diversity measures indicate that the increase of lactic acid bacteria regardless of treatment was the most relevant biological change in these samples. Surface pH was not different between treatments ($P = 0.16$) and decreased during storage ($P < 0.01$), and the overall color of the samples followed a decrease in lightness and redness that is often seen in beef stored for an extended period of time. In conclusion, *Lactococcus* became the dominant genus in all samples by day 56. Because organic acids are less effective at slowing the growth of these organisms, there was minimal distinction between treatment and control groups. When addressing spoilage of raw meat, interventions should be targeted to slow the growth of the bacteria known to cause spoilage in a specific product so that ineffective interventions are not used.

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Statistics Used in the Nebraska Beef Report and Their Purpose

The purpose of beef cattle and beef product research at UNL is to provide reference information that represents the various populations (cows, calves, heifers, feeders, carcasses, retail products, etc) of beef production. Obviously, the researcher cannot apply treatments to every member of a population; therefore he/she must sample the population. The use of statistics allows the researcher and readers of the Nebraska Beef report the opportunity to evaluate separation of random (chance) occurrences and real biological effects of a treatment. Following is a brief description of the major statistics used in the beef report. For a more detailed description of the expectations of authors and parameters used in animal science see Journal of Animal Science Style and Form at: http://jas.fass.org/misc/ifora.shtml.

—**Mean**: Data for individual experimental units (cows, steers, steaks) exposed to the same treatment are generally averaged and reported in the text, tables and figures. The statistical term representing the average of a group of data points is mean.

—**Variability**: The inconsistency among the individual experimental units used to calculate a mean for the item measured is the variance. For example, if the ADG for <u>all</u> the steers used to calculate the mean for a treatment is 3.5 lb then the variance is zero. But, this situation never happens! However, if ADG for individual steers used to calculate the mean for a treatment range from 1.0 lb to 5.0 lb, then the variance is large. The variance may be reported as standard deviation (square root of the variance) or as standard error of the mean. The standard error is the standard deviation of the mean as if we had done repeated samplings of data to calculate multiple means for a given treatment. In most cases treatment means and their measure of variability will be expressed as follows: 3.5 0.15. This would be a mean of 3.5 followed by the standard error of the mean of 0.15. A helpful step combining both the mean and the variability from an experiment to conclude whether the treatment results in a real biological effect is to calculate a 95% confidence interval. This interval would be twice the standard error added to and subtracted from the mean. In the example above, this interval is 3.2–3.8 lb. If in an experiment, these intervals calculated for treatments of interest overlap, the experiment does not provide satisfactory evidence to conclude that treatments effects are different.

—***P* Value**: Probability (*P* Value) refers to the likelihood the observed differences among treatment means are due to chance. For example, if the author reports P 0.05 as the significance level for a test of the differences between treatments as they affect ADG, the reader may conclude there is less than a 5% chance the differences observed between the means are a random occurrence and the treatments do not affect ADG. Hence we conclude that, because this probability of chance occurrence is small, there must be difference between the treatments in their effect on ADG. It is generally accepted among researchers when P values are less than or equal to 0.05, observed differences are deemed due to important treatment effects. Authors occasionally conclude that an effect is significant, hence real, if P values are between 0.05 and 0.10. Further, some authors may include a statement indicating there was a tendency or trend in the data. Authors often use these statements when P values are between 0.10 and 0.15, because they are not confident the differences among treatment means are real treatment effects. With P values of 0.10 and 0.15 the chance random sampling caused the observed differences is 1 in 10 and 1 in 6.7, respectively.

—**Linear & Quadratic Contrasts**: Some articles contain linear (L) and quadratic (Q) responses to treatments. These parameters are used when the research involves increasing amounts of a factor as treatments. Examples are increasing amounts of a ration ingredient (corn, by-product, or feed additive) or increasing amounts of a nutrient (protein, calcium, or vitamin E). The L and Q contrasts provide information regarding the shape of the response. Linear indicates a straight line response and quadratic indicates a curved response. P-values for these contrasts have the same interpretation as described above.

—**Correlation (r)**: Correlation indicates amount of linear relationship of two measurements. The correlation coefficient can range from 1 to 1. Values near zero indicate a weak relationship, values near 1 indicate a strong positive relationship, and a value of 1 indicates a strong negative relationship.

Animal Science
http://animalscience.unl.edu

Curriculum: The curriculum of the Animal Science Department at the University of Nebraska–Lincoln is designed so that each student can select from a variety of options oriented to specific career goals in professions ranging from animal production to veterinary medicine. With unique opportunities to double major in ***Grazing Livestock Systems*** (http://gls.unl.edu) or complete the ***Feedlot Management Internship Program*** (http://feedlot.unl.edu/intern)

Careers:

Animal Health
Banking and Finance
Animal Management
Consultant
Education
Marketing
Technical Service
Meat Processing
Meat Safety
Quality Assurance
Research and Development
Veterinary Medicine

Scholarships: The Animal Science Department also offers scholarships to incoming freshmen and upperclassmen. The department awards over $30,000 each year to Animal Science students.

ABS Global Scholarship
Baltzell-Agri-Products, Inc. Scholarship
Maurice E. Boeckenhauer Memorial Scholarship
Mike Cull Judging and Activities Scholarship
Don Geweke Memorial Award
Parr Young Senior Merit Award
Nebraska Pork Producers Association Scholarship
Waldo Family Farms Scholarship
Frank and Mary Bruning Scholarship
Art and Ruth Raun Scholarship
Animal Science Department Freshman Scholarship
Feedlot Management Scholarship
Robert Boeckenhauer Memorial Scholarship
Burnell Scholarship Fund
Doane Scholarship
Lincoln Coca-Cola Bottling Company Scholarship.
William J. and Hazel J. Loeffel Scholarship
Nutrition Service Associates Scholarship
Parr Family Student Support Fund
Chris and Sarah Raun Memorial Scholarship
Walter A. and Alice V. Rockwell Scholarship
Standard Manufacturing Co. Scholarship
Max and Ora Mae Stark Scholarship
D. V. and Ernestine Stephens Memorial Scholarship
Dwight F. Stephens Scholarship
Arthur W. and Viola Thompson Scholarship
Thomas H. Wake, III Scholarship
Frank E. Card Scholarship
Derrick Family Scholarship
G. H. Francke Livestock Judging Scholarship
Eric Peterson Memorial Award
Winkler Memorial Livestock Judging Scholarship

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ANIMAL SCIENCE
Institute of Agriculture and Natural Resources

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