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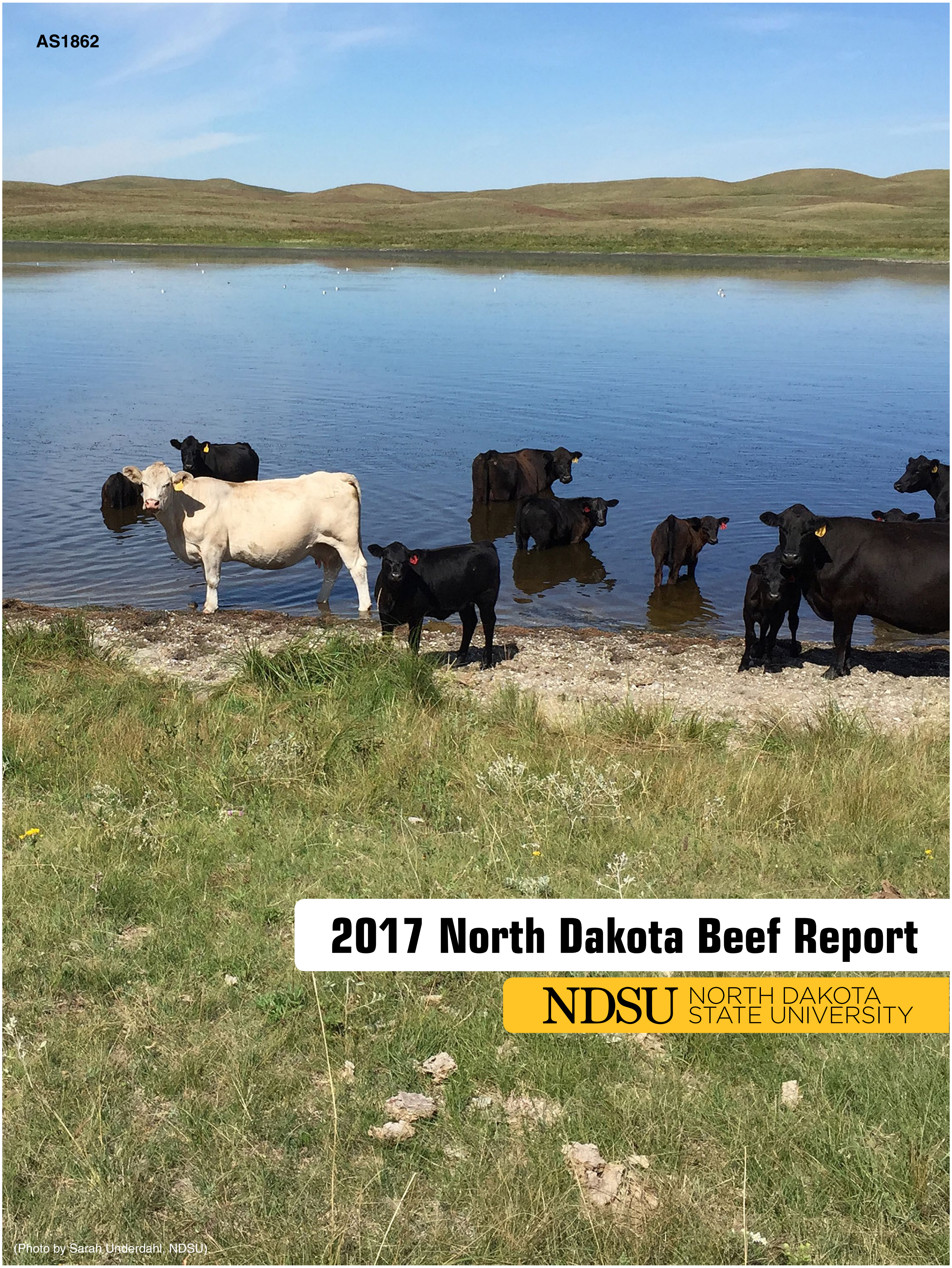

2017 North Dakota Beef Report

NDSU NORTH DAKOTA STATE UNIVERSITY

(Photo by Sarah Underdahl, NDSU).

2017 North Dakota Beef Report

Welcome to the 2017 North Dakota Beef Research Report.

North Dakota State University; the College of Agriculture, Food Systems, and Natural Resources; and the North Dakota Agricultural Experiment Station are pleased to be able to provide the report to the beef industry and cattle ranchers in the state. This report provides the most recent results from research related to beef cattle, beef products, and environmental and range sciences from North Dakota.

The beef research programs at the North Dakota Agricultural Experiment Station Main Station at Fargo and at the Research Extension Centers across North Dakota are dedicated to serving the producers and stakeholders in North Dakota by developing new knowledge and technology to improve the management, efficiency and production of high-quality cattle and beef using sustainable and safe approaches.

This report includes a broad range of research from on-campus departments, schools and centers, as well as Research Extension Centers across the state, and provides producers and stakeholders with one document that contains all beef-related research conducted at NDSU each year.

We thank the federal, state and industry sponsors who support our research programs. Without this support, this research would not be possible. We also thank all of the faculty, staff, and graduate and undergraduate students who have contributed to this work.

We hope you enjoy reading this research report and hope that the information is useful to your operation. We look forward to continuing to serve the North Dakota beef industry in the coming year and in the future.

Sincerely,

Ken Grafton
Vice President for Agricultural Affairs
Dean of the College of Agriculture, Food Systems, and Natural Resources
Director of the North Dakota Agricultural Experiment Station

"Resilience" is a term that suits North Dakota well.

By definition, resilience is the ability to recover from or adjust easily to misfortune or change. Despite the devastating effects of the 2017 drought on beef ranches, I know the beef industry will be resilient and will work hard to recover.

These are not easy times, but the industry is making wise choices to manage through the drought and will rebound successfully in the future. NDSU has been a major contributor to the research and information that has guided critical beef management decisions during the drought and more favorable times.

I thank the leaders and members of the beef industry for their ongoing support of beef research and Extension at NDSU. The NDSU Extension Service is able to provide the beef industry with research-based information in the areas of genetics and reproduction, nutrition, animal care and health, range management, resource stewardship and market economics through our Extension specialists and agents.

I thank the dedicated NDSU animal scientists and Extension specialists for their innovative and valuable research and Extension programs. The results of their numerous projects are reported between the covers of this 2017 North Dakota Beef Report. The report contains a wealth of information on current applied and basic research and project results. I hope you take time to review this information for ideas and to stay abreast of the latest in beef research at NDSU.

I encourage you to contact the scientists or Extension specialists who are involved in these projects if you have questions or wish to provide additional input. They always are interested in hearing your thoughts.

Thank you for your continued support of these beef research projects and the other animal science programs as well. We want to work together with you to support the successful future of North Dakota beef.

Sincerely,

Chris Boerboom
Director of the NDSU Extension Service

Contents

Performance of beef cows bale grazing poor-quality grass hay in winter with and without supplementation

Jessalyn Bachler[1], Stephanie Becker[1] and Michael Undi[1]

Ensuring that animals have adequate nutrition is important when bale grazing late in the season. For cows receiving poor-quality feed, this can be achieved by using supplementation methods that minimize labor and energy costs. This study examines methods of supplementing cows while bale grazing poor-quality hay. Preliminary results suggest that poor-quality grass hay offered to pregnant beef cows in early to midgestation in winter may not contain adequate energy, protein and phosphorus to meet animal requirements. Supplements such as corn dried distillers grains with solubles (DDGS) will provide the extra nutrients required to meet this nutrient shortfall, but alfalfa hay or liquid supplements will not make up for this shortfall.

Summary

This study was conducted to investigate methods of supplementing beef cows bale grazing poor-quality hay during the winter in North Dakota. Nonlactating pregnant Angus cows (n = 64; body weight [BW] = 1,312 ± 142 pounds; body condition score [BCS] = 5.6 ± 0.31) were assigned to one of eight groups of similar total body weight and kept on bale-grazing pasture during the winter months. The following bale grazing treatments were examined: a) poor-quality hay, b) poor-quality hay supplemented with alfalfa hay, c) poor-quality hay supplemented with corn DDGS and d) poor-quality hay treated with a liquid supplement. Two-day BWs were taken at the start and end of the study. Two observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese) at the start and end of the study. Despite heavy snow accumulation that resulted from three blizzards and one winter storm, cows were able to bale graze for 70 days before the termination of the study. Supplementing cows with DDGS while bale grazing poor-quality hay resulted in greater ($P < 0.05$) BW gain and BCS change relative to other treatments. Cows supplemented with alfalfa or liquid supplement lost weight and body condition, which might indicate that these supplements did not supply adequate energy to meet animal demands. Preliminary results suggest a need for higher energy supplements during the winter months in the northern Plains.

Introduction

Beef cattle in the northern Plains typically graze poor-quality forages in the winter (Marshall et al. 2013). Poor-quality forages are generally low in energy, protein and minerals, impairing rumen microbial function, which leads to poor forage intake and digestion (Köster et al., 1996). Utilization of poor-quality forages can be improved through supplementation, which is especially important at critical times such as summer plant dormancy or fall and winter months (Caton and Dhuyvetter, 1997).

Effective supplementation requires regular supplement intake at levels that do not vary significantly on a daily basis (Garossino et al., 2003). Cost-effective supplement delivery methods help minimize feed costs by delivering supplement to the grazing cattle less frequently (Schauer et al., 2005; Canesin et al., 2014) or eliminating pasture visits altogether (Klopfenstein and Owen, 1981).

Although the majority of producers in the northern Plains keep cattle in dry lot pens in the winter (Asem-Hiablie et al., 2016), producers are interested in extending the grazing season by keeping cattle on pasture. The adoption of extended grazing is driven by reductions in winter feed costs associated with moving cattle away from dry lots (Kelln et al., 2011).

Supplementation techniques that minimize or eliminate pasture visits in extended grazing systems will further the goal of minimizing winter feed costs. This study was conducted to investigate methods of supplementing cows bale grazing poor-quality hay in the winter. The study examined beef cow performance, cost effectiveness of bale grazing supplementation strategies, forage production and soil nutrient changes resulting from supplementation strategies.

[1]Central Grasslands Research Extension Center, NDSU

Experimental Procedures

This study was conducted from Nov. 4, 2016, to Jan. 12, 2017, at the Central Grasslands Research Extension Center near Streeter, N.D. Nonlactating pregnant Angus cows (n = 64; BW = 1,312 ± 142 pounds; BCS = 5.6 ± 0.31) were assigned to eight groups of similar total body weight and kept on bale-grazing pasture in the winter months. The cows were pregnancy-checked prior to the start of the study to eliminate open cows. Cows were treated with IVOMEC (Ivermectin) pour-on during sorting.

The bale grazing site was a 26-acre field that was historically cropland, using a corn and small grain rotation. In the two years prior to this study, the site was planted to cool-season cover crops, mainly annual rye grass and brassicas. The site was sprayed with 2,4-D and glyphosate in late April 2016 and seeded to a meadow brome grass, which was planted in early May 2016.

The field then was divided into eight, three-acre paddocks using four-strand, high-tensile wire electric fencing. One water tank was installed between two paddocks. The site was mowed prior to bale placement to reduce the possibility of cows grazing standing forage.

Forty round hay bales were placed in each paddock in two rows at 50 feet apart in the fall of 2016. Net wrap was removed prior to feeding. Bales were placed on their sides to reduce waste and loss of liquid supplement. Cows were allotted four bales at a time, and access to new bales was controlled using portable electric fencing.

Cows were moved to a new set of bales when the depth of waste feed remaining across the diameter of each bale was less than 4 inches. Windbreaks were placed in each paddock for protection. Cows were allowed *ad libitum* access to fresh water, mineral supplement and salt blocks.

Cows were assigned to one of four bale grazing treatments as follows: a) poor-quality hay (control), b) poor-quality hay supplemented with alfalfa hay, c) poor-quality hay supplemented with corn DDGS and d) poor-quality hay treated with a liquid supplement (Table 1). Poor-quality hay was obtained from a Conservation Reserve Program (CRP) field of mixed cool-season grasses that had not been harvested for several years.

Cows supplemented with DDGS were fed 4 pounds of DDGS/head/day twice weekly. Approximately 9 gallons of liquid supplement (Quality Liquid Feeds Inc.) was poured onto upright bales. This amount of liquid supplement was calculated to increase hay protein content by approximately 3 percentage points. Bales were allowed to sit upright after pouring until the supplement had seeped into the bale, after which the bales were flipped on their sides. One bale of alfalfa hay was fed for every three bales of poor-quality hay.

Cows were allowed *ad libitum* access to water. Cows on the control, alfalfa hay and liquid supplement hay treatments were fed a 6-12+ mineral supplement (CHS Inc., Sioux Falls, S.D.). All cows were offered a salt block.

Two-day body weights were taken at the start and end of the study. Two observers assigned BCS using a 9-point system (1 = emaciated, 9 = obese; Wagner et al., 1988) at the start and end of the study. Animal handling and care procedures were approved by the NDSU Animal Care and Use Committee.

Results and Discussion

During the first year of this study (winter 2016-2017), the bale grazing trial was marked by three severe blizzards and one winter storm, which led to heavy snow accumulation in the paddocks. Despite snow depths greater than 20 inches in select places, cows were able to bale graze for 70 days before the termination of the study. The trial was terminated because cows no longer were able to reach the water source due to the heavy snowfall.

Poor-quality grass hay offered to cows was low in energy, protein and phosphorus, supplying 97, 95 and 60 percent, respectively, of the energy, protein and phosphorus required by cows in the early to

Table 1. Composition of poor-quality grass hay supplemented with alfalfa hay, a liquid supplement or DDGS.

	Control[1]	ALF[2]	QLF[3]	DDGS[4]
DM, %	94.3	94.1	86.4	93.7
Nutrient composition, % DM				
CP	7.5	9.9	8.8	11.1
TDN	51.7	54.1	51.0	55.2
NDF	66.3	63.5	65.9	60.9
ADF	47.8	44.7	48.7	42.6
Ca	0.56	0.91	0.51	0.48
P	0.10	0.11	0.16	0.25
K	0.77	1.03	0.93	0.84
Mg	0.18	0.23	0.15	0.21

[1]Grass hay, [2]grass hay + alfalfa hay, [3]liquid supplement-treated hay and [4]grass hay + DDGS.

midgestation. Cows supplemented with DDGS maintained BW and BCS, suggesting that cow nutrient requirements were met by DDGS supplementation to cows grazing poor-quality grass hay. Alfalfa hay or liquid supplement did not influence final BW or BCS relative to the control (Table 2). Preliminary results suggest that poor-quality grass hay offered to pregnant beef cows in early to midgestation in the winter may not contain adequate energy, protein and phosphorus to meet animal requirements. Supplements such as corn DDGS will provide the extra nutrients required to meet this nutrient shortfall, but alfalfa hay or liquid supplements will not make up for this shortfall.

Table 2. Animal performance of cows bale grazing poor-quality grass hay supplemented with alfalfa hay, a liquid supplement or DDGS.

	Supplementation					
	Control[1]	ALF[2]	QLF[3]	DDGS[4]	SE	*P*-value
Initial BW, lbs.	1,316	1,301	1,314	1,316	51.4	0.99
Final BW, lbs.	1,264	1,269	1,277	1,357	52.4	0.25
Gain, lbs./day	-0.74[b]	-0.45[b]	-0.52[b]	0.58[a]	0.145	<0.001
Initial BCS	5.6	5.6	5.5	5.5	0.10	0.67
Final BCS	5.4	5.4	5.4	5.5	0.09	0.21
BCS change	-0.24[b]	-0.17[b]	-0.16[b]	0.07[a]	0.083	0.003

[1]Grass hay, [2]grass hay + alfalfa hay, [3]liquid supplement-treated hay and [4]grass hay + DDGS.
[a,b]Means in the same row followed by a different letter differ significantly ($P < 0.05$).

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Moderate nutrient restriction influences expression of genes impacting production efficiencies of beef cattle in fetal liver, muscle and cerebrum by day 50 of gestation

Matthew S. Crouse[1], Joel S. Caton[1], Robert A. Cushman[2], Kyle J. McLean[1,3], Carl R. Dahlen[1], Pawel P. Borowicz[1], Lawrence P. Reynolds[1] and Alison K. Ward[1]

The objectives of this study were to determine the effect of a moderate maternal nutrient restriction during the first 50 days of gestation on the expression of genes impacting production efficiencies in the fetal liver, muscle and cerebrum. The results indicate that a moderate maternal nutrient restriction during the first 50 days of gestation does affect the expression of genes involved in the fetal liver, muscle and brain, which may program the offspring for poor growth and development trajectories throughout postnatal life.

Summary

We hypothesized that a moderate maternal nutrient restriction during the first 50 days of gestation in beef heifers would affect expression of genes impacting production efficiency phenotypes in the fetal liver, muscle and cerebrum. Fourteen Angus-cross heifers were estrus synchronized and assigned at breeding to one of two dietary treatments (CON – 100 percent of nutrient requirements to gain 1 pound/day; RES – 60 percent of CON). At day 50 of gestation, heifers were ovariohysterectomized, and the fetal liver, muscle and cerebrum were collected. For the fetal liver, muscle and cerebrum, a total of 548, 317 and 151 genes, respectively ($P < 0.01$) were differentially expressed (up or down regulated). Differentially expressed genes were screened to determine whether they fit into functional categories associated with known impacts on production efficiencies. In the fetal liver, three functional categories of interest were affected by nutritional treatment: metabolic pathways, protein kinase and nucleosome core. In the fetal muscle, two functional categories of interest were affected by nutritional treatment: skeletal muscle and embryogenesis. In the fetal cerebrum, three functional categories of interest were affected by nutritional treatment: hippocampus and neurogenesis, metal-binding and cytoskeleton. These results demonstrate that a moderate maternal nutrient restriction during the first 50 days of gestation in beef heifers alters expression of genes impacting production efficiencies in the fetal liver, muscle and cerebrum. With these data, we can conduct further research identifying the physiological changes to these tissues and the effects these changes have on production efficiencies in beef cattle. Finally, identifying specific supplementation strategies to prevent the potentially negative consequences of poor maternal nutrition on offspring growth and development will provide additional means to increase production efficiencies in beef cattle. Emerging targets include liver metabolism and feed efficiency, muscle development and tenderness, as well as programmed cerebral formation and temperament.

Introduction

During the early phase of fetal development, placental growth and differentiation, as well as formation of fetal organs, occur. All of these are critical events for normal fetal development (Funston et al., 2010).

Additionally, dams that undergo stress (nutritional, environmental, etc.) during the beginning of gestation but not the end are likely to produce a normal birth weight offspring that still may suffer from poor growth and metabolic issues because of the stress early in pregnancy (Ford et al., 2007; Vonnahme et al., 2007; Reynolds and Caton, 2012). These stress-induced changes may arise by affecting gene expression in tissues such as the liver, muscle and brain, thus "programming" potential susceptibilities to metabolic issues and reduced performance (Waterland and Jirtle, 2004).

Therefore, we hypothesized that a moderate maternal nutrient restriction during the first 50 days of gestation in beef heifers would affect gene expression in the fetal liver, muscle and cerebrum, thereby programming susceptibilities to impaired performance and altered carcass characteristics postnatally.

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Experimental Procedures

Animals, Experimental Design and Treatments

Protocols described herein were approved by the North Dakota State University Institutional Animal Care and Use Committee. Angus-cross heifers (n = 14, about 16 months of age; average initial body weight [BW] = 690 ± 55 pounds) were obtained from the Central Grasslands Research Extension Center (Streeter, N.D.) and housed at the NDSU Animal Nutrition and Physiology Center (Fargo, N.D.).

The heifers were acclimated to individual bunk feeding for two weeks before the beginning of the trial. All heifers were exposed to the 5-d CO-Synch + CIDR estrus synchronization protocol (Bridges et al., 2008) and bred via artificial insemination (AI) to a common sire at 12 hours after observed estrus.

Immediately post-breeding, heifers were assigned randomly to one of two treatment groups. Control heifers (CON, n = 7), received 100 percent of National Research Council (2000) requirements for 1 pound/day gain to reach 80 percent of mature BW at first calving (actual average daily gain [ADG] = 1.12 pounds/day).

Restricted heifers (RES, n = 7), were placed on a 40 percent global nutrient restriction, which was accomplished by reducing total diet delivery to 60 percent of the control delivery (actual ADG = minus 0.18 pound/day). The diet was delivered via total mixed ration (TMR) and consisted of grass hay, corn silage, alfalfa haylage, grain and a mineral mix, as well as dried distillers grains with solubles.

Tissue Collection and Analysis

Ovariohysterectomy procedures were conducted as described by McLean et al. (2016) on day 50 of gestation for all heifers. Following ovariohysterectomy, the fetal liver, muscle from the hind limb and cerebrum tissues were collected using a stereoscope for increased visualization and to ensure maximum yield of tissue. Ribonucleic acid (RNA) was extracted and RNA-seq analysis was conducted to determine differences in expression of genes.

For the fetal liver, muscle and cerebrum, a total of 548, 317 and 151 genes (*P* < 0.01) were differentially expressed. Differentially expressed genes were screened to determine whether they fit into functional categories of pathways or ontologies associated with known impacts on production efficiencies.

Results and Discussion

Liver

Three functional categories of interest were determined for the fetal liver tissues: metabolic pathways, protein kinase and nucleosome core (Table 1). The metabolic pathways category (n = 43 genes; *P* = 0.02) comprised six proposed functions (Table 1):

- Amino acid metabolism (n = 10) was made up of five genes upregulated in RES and five upregulated in CON.
- All differentially expressed purine and pyrimidine metabolism genes (n = 7) were upregulated in RES.
- Carbohydrate metabolism (n = 10) comprised five genes upregulated in RES and five upregulated in CON.
- All differentially expressed reducing equivalent metabolism genes (n = 5) were upregulated in RES.
- Steroid and lipid biosynthesis (n = 9) were affected by treatment such that eight genes were upregulated in RES and one was upregulated in CON.
- Cytochrome and heme metabolism (n = 2) were affected by treatment such that both genes were upregulated in RES.

The protein kinase category (n = 47 genes; *P* = 0.02) comprised three proposed functions (Table 1):

- Serine/threonine protein kinase (n = 22) yielded 21 genes that were upregulated in RES and one gene upregulated in CON.
- ATP-binding function (n = 19) was made up of 15 genes upregulated in RES and four upregulated in CON.
- Nucleotide-binding (n = 6), of which four were upregulated in RES and two were upregulated in CON.

The nucleosome core category (n = 22 genes; *P* = 0.005) comprised two proposed functions (Table 1):

- All differentially expressed histones (n = 9) were upregulated in RES.
- Histone modifiers (n = 13 genes) comprised 12 genes upregulated in RES and one gene upregulated in CON.

Muscle

Three categories of interest were determined for fetal muscle tissue: skeletal muscle, embryogenesis and signaling cascades (Table 1). The skeletal muscle category (n = 74 genes; *P* < 0.001) comprised eight proposed functions (Table 1):

- Contraction genes (n = 9) all were upregulated in RES.
- Intermediate filament genes (n = 11) had seven genes that were upregulated in RES and four that were upregulated in CON.
- Microtubule-associated genes (n = 10) contained two genes upregulated in RES and 10 upregulated in CON.
- Actin (n = 4) was made up of three genes upregulated in RES and one upregulated in CON.
- All genes associated with myosin and troponin (n = 4 and n = 6 genes, respectively) were upregulated in RES.
- Twenty-five genes were associated with calcium-binding in

skeletal muscle, of which 14 were upregulated in RES and the remaining upregulated in CON.
- All differentially expressed ATP-binding genes (n = 5) were upregulated in CON.

The embryogenesis category (n = 14 genes; P < 0.001) comprised two functional ontologies (Table 1):

- Myogenesis (n = 2) had two genes that were upregulated in RES.
- Homeobox-related genes (n = 12) had 10 that were upregulated in RES and two that were upregulated in CON

Cerebrum

Three categories of interest were determined for fetal cerebrum: hippocampus and neurogenesis, metal-binding and cytoskeleton (Table 1).

The hippocampus and neuro-genesis category (n = 32 genes; $P < 0.001$) comprised five proposed functional annotations (Table 1):

- Hippo signaling pathway had five genes that were upregulated in RES.
- All differentially expressed collagen genes (n = 9) were upregulated in RES.
- Netrin genes (n = 5) all were upregulated in RES.

Table 1. Functional categories and predicted roles for differentially expressed genes that impact production efficiencies ($P < 0.01$) in fetal liver, muscle from hind limb and cerebrum.

Tissue	Category	Functional annotation[1]	Total genes[2]	RES[3]	CON[4]	*P*-value[5]
Liver	Metabolic pathways	Amino acid	10	5	5	0.02
		Purine and pyrimidine	7	7	0	
		Carbohydrate	10	5	5	
		Reducing equivalent (NAD/FAD)	5	5	0	
		Steroid and lipid biosynthesis	9	8	1	
		Cytochrome and heme	2	2	0	
	Protein kinase	Serine/threonine protein kinase	22	21	1	0.02
		ATP-binding	19	15	4	
		Nucleotide-binding	6	4	2	
	Nucleosome core	Histones	9	9	0	0.005
		Histone modifiers	13	12	1	
Muscle	Skeletal muscle	Contraction	9	9	0	< 0.001
		Intermediate filament	11	7	4	
		Microtubule	10	2	8	
		Actin	4	3	1	
		Myosin	4	4	0	
		Troponin	6	6	0	
		Calcium-binding	25	14	11	
		ATP-binding	5	0	5	
	Embryogenesis	Myogenesis	2	2	0	< 0.001
Cerebrum	Hippocampus and neurogenesis	Hippo signaling pathway	5	5	0	< 0.001
		Collagen	9	9	0	
		Netrin	5	5	0	
		SMAD	4	4	0	
		Developmental protein	9	8	1	
	Metal-binding	Iron-binding	4	4	0	0.006
		Zinc-binding	10	10	0	
		Copper-binding	2	2	0	
		Nickel-binding	1	1	0	
		Calcium-binding	6	5	1	
	Cytoskeleton	Actin remodeling	5	5	0	0.003

[1]Proposed function of differentially expressed genes that fall under a specific category.
[2]Total number of differentially expressed genes associated with a specific function.
[3]Number of differentially expressed genes that are upregulated in RES fetuses.
[4]Number of differentially expressed genes that are upregulated in CON fetuses.
[5]Probability value associated with a specific category.

- Genes associated with the SMAD protein (n = 4) all were upregulated in RES.
- Genes that encompass developmental proteins (n = 9) were made up of eight genes that were upregulated in RES and one gene that was upregulated in CON.

The metal-binding category (n = 23 genes; $P = 0.006$) comprised five metal binding functional annotation groups (Table 1):

- All differentially expressed iron-binding genes (n = 4) were upregulated in RES.
- All differentially expressed zinc-binding genes (n = 10) were upregulated in RES.
- Copper and nickel binding genes (n = 2 and n = 1, respectively) all were upregulated in RES.
- Calcium-binding genes (n = 6) had five genes that were upregulated in RES and one that was upregulated in CON.

The cytoskeleton category (n = 5) was made up of actin remodeling genes, of which all five were upregulated in RES.

Discussion

Altering liver function by modifying metabolism in rats from restricted mothers has resulted in permanent changes in key hepatic enzyme and kinase activities in a direction that potentially would bias the liver toward a "starved" setting (Desai and Hales, 1997).

These data may be reflected in our differentially expressed metabolism and protein kinase genes, as well as resulting in modifications to carbohydrate and amino acid, and reducing equivalent metabolism, which are highly intertwined and may result in the similar metabolic consequences previously observed in other species.

Our findings of altered genes related to core histones also are supported by observations of nutrient restriction in mothers resulting in modification of transcriptional regulators such as core histones in rat pups (Tosh et al., 2010). Histone modification is critical because it can impact gene expression, chromosome packaging and DNA damage/repair (Wood, 2004).

The fetal stage is crucial for skeletal muscle development in mammalian livestock because they have no net increase in the muscle fiber number after birth (Stickland, 1978; Zhu et al., 2004). Therefore, any impacts of maternal nutrition during gestation have lifelong consequences. Greenwood et al. (2004) demonstrated that steers born from cows nutritionally restricted during late gestation had reduced BW and carcass weights at 30 months of age, compared with steers from cows fed adequately.

Muscle fibers are formed throughout gestation during primary and secondary myogenesis, and at day 50 of gestation, peak primary myogenesis is occurring (Yan et al., 2013), with secondary myogenesis taking place during the second and third trimester (Russell and Oteruelo, 1981). Our data suggest that genes involved in skeletal muscle formation and function were altered by maternal nutritional treatment, which may affect total fiber development during gestation. Additionally, affecting genes involved in muscle function, more specifically contraction, may affect muscle function postnatally and potentially tenderness after slaughter.

The hippocampus in the cerebrum of the brain plays an integral part in emotion and memory and also is linked to anxiety (Engin and Treit, 2007). Key functional proteins in the brain such as collagen, actin filaments and metal-binding proteins play important roles in maintaining proper synapse and neuronal function, which if altered, may lead to brain disorders such as schizophrenia and abnormal startle response (Lamprecht, 2014; Cristovao et al., 2016; Su et al., 2016). Changes to these cerebrum functions in cattle as observed in our data (at least at the mRNA level) may indicate that poor maternal nutrition during early gestation may program cattle for a flighty temperament, thereby decreasing production efficiencies.

Acknowledgments

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Effects of maternal nutrition on the expression of neutral and acidic amino acid transporters in bovine uteroplacental tissues from days 16 to 50 of gestation

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The objective of this study was to determine the effects of maternal nutritional status on the mRNA expression of neutral and acidic AA (amino acid) transporters: SLC1A1, SLC1A5, SLC7A5, SLC38A2, and SLC38A7 in uterine and fetal tissues on days 16, 34, and 50 of gestation. Maternal nutrition influenced only the expression of SLC38A7 in intercaruncular tissue; however, day of gestation affected the expression of SLC1A1 and SLC38A7 in intercaruncular and the expression of SLC1A5 and SLC38A2 in fetal tissues. These data suggest that neutral and acidic amino acid solute carriers (SLC) are influenced by the development of the fetus during advancing gestation, regardless of maternal nutritional status. The transporter SLC38A7 preferentially transports glutamine, which is a major energetic fuel for fetal development, and difference in expression due to nutritional treatment may suggest a compensatory mechanism to increase glutamine availability to fetuses from restricted dams.

Summary

We hypothesized that day of gestation and maternal nutrition would alter the relative mRNA expression of neutral and acid amino acid (AA) transporters *SLC1A1, SLC1A5, SLC7A5, SLC38A2* and *SLC38A7* in bovine uteroplacental tissues from days 16 to 50 of gestation. Crossbred Angus heifers (n = 49) were synchronized, bred via artificial insemination (AI), assigned to nutritional treatment (CON = 100 percent of National Research Council [NRC] requirements for 1 pound per day of gain and RES = 60 percent of CON) and ovariohysterectomized on day 16, 34 or 50 of gestation (n = 6 to 9/day). Nonbred, nonpregnant (NB-NP) controls were ovariohysterectomized on day 16 of the estrous cycle (n = 6) after synchronization. The resulting arrangement was a 2 × 3 factorial + 1 (CON vs. RES × day 16, 34 or 50 + NB-NP controls). Tissues collected included intercaruncular endometrium, **ICAR** and fetal membranes, **FM** [chorioallantois]. FM was not collected from NB-NP heifers due to the lack of the tissues being present. Relative expression of the nutrient transporters *SLC1A1, SLC1A5, SLC7A5, SLC38A2* and *SLC38A7* was determined for ICAR using NB-NP-ICAR tissues for the baseline; for FM, NB-NP endometrium served as the baseline. In ICAR, the relative mRNA expression of *SLC38A7* experienced a day × treatment interaction, where day 16 RES was greater ($P < 0.01$) than day 16 CON, which was greater than day 50 RES. Furthermore, day of gestation affected the expression of SLC1A1, where day 16 was greater ($P < 0.01$) than days 34 and 50. In FM, the expression of SLC1A5 was greater on day 34, compared with day 50. Additionally, a main effect of day was observed for the expression of *SLC38A2*, where days 34 and 50 were greater ($P < 0.01$) than day 16 of gestation. These data support our hypothesis that day of gestation and maternal nutrition affect the relative mRNA expression of AA transporter *SLC38A7* in ICAR, while day of gestation has a greater effect on the relative mRNA expression of other neutral and acidic AA transporters in ICAR and FM. These data suggest that nutrient transporters are influenced by development of the fetus during advancing gestation more so than maternal nutritional status.

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Introduction

Early in gestation, a shared conceptus-maternal blood flow has yet to be established; therefore, the conceptus is completely reliant upon histotroph (Bazer, 1975). Uterine glands, which are found in the endometrium (innermost tissue layer of the uterus), secrete histotroph into the uterine lumen for use by the conceptus. Components of histotroph include AA, glucose, fructose and vitamins (Bazer et al., 2012). Amino acids play critical roles in the proper development of the conceptus (Kwon et al., 2003).

These AA supplied to the conceptus can be divided into subcategories of neutral, acidic and basic. The reliance of the conceptus on histotroph was further demonstrated via a uterine gland knockout model in sheep, where destruction of uterine glands resulted in loss of conceptus viability (Gray et al., 2001).

Due to the lack of umbilical blood flow and shared blood flow across the placenta during early gestation, the transporters of these nutrients are necessary for conceptus development. Therefore, determination of how maternal nutrition affects the expression of these transporters may lead to future applied research resulting in strategic supplementation of specific AA at specific points in gestation, with the goal of increasing reproductive efficiency in the beef industry. An increase in reproductive efficiency could aid in the efforts of the beef industry to produce one calf per cow per year.

Collectively, the neutral and acidic AA transporters *SLC1A1, SLC1A5, SLC7A5, SLC38A2* and *SLC38A7* transport the majority of the 17 neutral and acidic AA. Therefore, we tested the hypothesis that day of gestation and maternal nutrition would impact the mRNA expression of neutral and acidic AA transporters *SLC1A1, SLC1A5, SLC7A5, SLC38A2* and *SLC38A7*.

Experimental Procedures

All animal procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee. Crossbred Angus heifers (n = 49, about 15 months of age; average initial body weight [BW] = 716 pounds) were exposed to the 5-day CO-Synch + CIDR estrus synchronization protocol. Six heifers were not inseminated to serve as nonpregnant controls but received an ovariohysterectomy on day 16 of the subsequent synchronized estrous cycle. The remaining heifers (n = 6 to 9/day of gestation/treatment) were bred by AI to a common sire at 12 hours after observed estrus and ovariohysterectomized at days 16, 34 and 50 of gestation.

Immediately following the ovariohysterectomy, intercaruncular tissue from the horn ipsilateral to the corpus luteum (the uterine horn containing the conceptus) was collected. Also, fetal membranes (chorioallantois) were obtained.

Fetal membranes were collected only on days 16, 34 and 50 of gestation in pregnant females; nonpregnant controls did not have fetal membranes. All tissues were frozen immediately in liquid nitrogen-cooled isopentane and stored at minus 112 F.

Expression of *SLC1A1, SLC1A5, SLC7A5, SLC38A2* and *SLC38A7* was determined by first isolating and purifying RNA from collected tissue samples. Following RNA extraction, real-time quantitative PCR (qPCR) was used to determine differences in mRNA expression of the neutral and acidic AA transporters in each tissue relative to a NB-NP endometrium sample.

Results and Discussion

ICAR

For SLC1A1, expression was greater ($P < 0.01$) on day 16 (39.11-fold), compared with days 34 and 50 (3.66- and 2.24-fold, respectively; Table 1; SEM = 6.29). Expression of *SLC38A2* tended ($P = 0.06$) to be greater in pregnant heifers (12.45-fold), compared with NB-NP heifers and tended ($P = 0.08$) to be greater on day 34, compared with day 50 (Table 1).

A day × treatment interaction was observed ($P < 0.01$) for the expression of SLC38A7, where day 16 RES (12.40-fold) was greater ($P \leq 0.05$) than day 16 CON (4.61-fold), day 34 CON and RES (2.2- and 1.47-fold, respectively), and day 50 CON and RES (1.49- and 0.74-fold, respectively; Table 1; SEM = 1.28). Furthermore, day 16 CON (4.61-fold) was greater ($P \leq 0.05$) than day 50 RES (0.74-fold), with day 34 CON and RES (2.23- and 1.47-fold, respectively) and day 50 CON (1.49-fold) being intermediate (SEM = 1.28).

FM

For *SLC1A5*, expression was greater ($P = 0.02$) on day 34 (0.93-fold), compared with day 50 (0.16-fold) of gestation, while day 16 (0.53-fold) was intermediate and not significantly different from either day (Table 2; SEM = 0.22). A main effect of day was observed ($P < 0.01$) for the expression of *SLC38A2*, where days 34 and 50 (0.46- and 0.59-fold, respectively) were greater than day 16 (0.13-fold) of gestation (Table 2; SEM = 0.09).

Discussion

As previously mentioned, nutrient transporters such as the ones investigated in this study are necessary for the fetus to receive the proper nutrition. This is especially true during early gestation because conceptus-maternal blood flow has yet to be established. Without proper nutrition, growth and development can be altered, resulting in intrauterine growth restriction. This can lead to developmental issues after birth and even result in loss of conceptus life (Wu et al., 2004).

Fetal growth and development is most vulnerable to maternal nutrition during the first third of gestation (Wu et al., 2004). Furthermore, the AA transported by the transporters investigated play important roles in the growth of the conceptus. Therefore, determination of the expression of these transporters in uterine and placental tissues is a key piece in determining the transport profile of neutral and acidic AA.

These data support our hypothesis in that day of gestation and maternal nutrition affected the relative expression of *SLC38A7* in ICAR. However, day of gestation had a greater effect on the other transporters investigated in ICAR and FM.

With the developing fetus being most vulnerable to maternal nutritional status during the first third of gestation, the effects of maternal nutritional status on specific nutrients and nutrient transporters may be more apparent during the first trimester of gestation. This is supported by the difference observed for the relative mRNA expression of *SLC38A7* in ICAR, where day 16 RES heifers were greater than day 16 CON heifers.

One of the preferred substrates of *SLC38A7* is glutamine. Glutamine is a major energy source for the conceptus during development (Kim et al., 2010) and it plays a role in osmoregulation in fetal fluids (Wu et al., 2014). Attachment of the embryo in cattle begins simultaneously (around day 17), with the differences observed in treatments for the expression of *SLC38A7* on day 16 of gestation. This may indicate the importance of *SLC38A7* to the proper growth and development of the conceptus around day 16 of gestation.

Once histotroph has been secreted into the uterine lumen, the associated nutrients must pass through the chorioallantois and amnion to reach the developing conceptus. In FM (chorioallantois), we observed that relative expression of *SLC1A5* was greater on day34, compared with day 50. Also, the expression of *SLC38A2* was greater on days 34 and 50, compared with day 16.

Around day 34 of gestation in cattle, a differentiation of the dorsal portion of the conceptus, greater organization of the developing vertebrate and further development of the limbs occur, along with organogenesis (Winters et al., 1942). *SLC1A5* and *SLC38A2* are known to transport alanine and serine.

While we know that these AA have functions related to gluconeogenesis (Wu et al., 2014), serine also aides in the control of gene expression through DNA methylation (Wu et al., 2009) and cell proliferation through DNA synthesis (Kwon et al., 2003). Therefore, these data may show a relationship between the transporters' known substrates and the proper cellular growth and dif-

Table 1. Level of expression of nutrient transporters *SLC1A1*, *SLC1A5*, *SLC7A5*, *SLC38A2* and *SLC38A7* in intercaruncular (ICAR) tissue due to CON and RES dietary treatments from days 16 to 50 of gestation and in nonbred nonpregnant (NB-NP) controls set to 1.

			Day of Gestation[1]					Maternal Status[2]		*P* – values[3]					
Gene[4]	Nutr. Trt[5]		16	34	50	Avg. Trt[6]	SEM[7]	NB-NP	Preg	Day	Trt	Day × Trt	NB-NP vs. Preg	16 vs. 34 + 50	34 vs. 50
SLC1A1	CON		34.25	2.88	2.76	13.30	8.87	1.00	15.00	< 0.01	0.64	0.82	0.14	< 0.01	0.85
	RES		43.99	4.44	1.71	16.71									
		Day[8]	39.11^{g}	3.66^{h}	2.24^{h}										
SLC1A5	CON		3.49	3.27	1.96	2.91	1.25	1.00	2.70	0.51	0.69	0.66	0.22	0.21	0.91
	RES		3.58	1.55	2.34	2.49									
		Day	3.53	2.41	2.15										
SLC7A5	CON		0.68	1.80	3.09	1.85	1.10	1.00	2.09	0.56	0.60	0.56	0.34	0.32	0.59
	RES		2.27	2.43	2.29	2.33									
		Day	1.47	2.11	2.69										
SLC38A2	CON		7.77	18.29	9.89	11.99	5.59	1.00	12.45	0.23	0.84	0.41	0.06	0.99	0.08
	RES		17.25	16.33	5.11	12.90									
		Day	12.51	17.31	7.50										
SLC38A7	CON		4.61^{b}	2.23^{bc}	1.49^{bc}	2.78	1.28	1.00	3.83	< 0.01	0.05	< 0.01	–	–	–
	RES		12.40^{a}	1.47^{bc}	0.74^{c}	4.87									
		Day	8.51	1.85	1.11										

[1]Day of Gestation = number of days after insemination. Each gene expression is given as a fold change in relation to NB-NP level of expression set to 1.

[2]Maternal Status = Determination of heifer cyclicity or pregnancy. Average gene expression of gestating heifers is expressed as a fold change relative to the NB-NP level of expression set to 1.

[3]Probability values for effect of day, treatment and day × treatment on level of expression of individual genes. Probability values for the contrast of mRNA.

[4]Gene = *SLC1A1* and *SLC1A5* – solute carriers family 1, members 1 and 5. *SLC7A5* – solute carrier family 7, member 5. *SLC38A2* and *SLC38A7* – solute carriers family 38, members 2 and 7.

[5]CON = Heifers fed a diet that meets 100 percent of NRC requirements to gain 0.45 kg daily. RES = Heifers restricted to 60 percent of CON diet.

[6]Mean level of expression across treatment within day and gene of interest.

[7]Average SEM for day × treatment interaction - day 16 CON n = 7, day 16 RES n = 7, day 34 CON n = 6, day 34 RES n = 9, day 50 CON n = 7, day 50 RES n =7.

[8]Mean level of expression of treatment group across day of gestation within tissue and gene of interest.

[a-c]Means within gene without a common superscript differ($P \leq 0.05$).

[g-h]Means within row without a common superscript differ($P \leq 0.05$).

Table 2. Level of expression of nutrient transporters *SLC1A1*, *SLC1A5*, *SLC7A5*, *SLC38A2* and *SLC38A7* in fetal membrane FM tissue due to CON and RES dietary treatments from days 16 to 50 of gestation and in nonbred nonpregnant (NB-NP) controls set to 1.

Gene[3]	Nutr. Trt[4]		Day of Gestation[1] 16	34	50	Avg. Trt[5]	SEM[6]	P – values[2] Day	Trt	Day x Trt	16 vs. 34 + 50	34 vs. 50
SLC1A1	CON		0.03	0.04	0.06	0.04	0.04	0.98	0.90	0.82	0.87	0.94
	RES		0.04	0.05	0.03	0.04						
		Day[7]	0.04	0.04	0.04							
SLC1A5	CON		0.65	1.29	0.13	0.69	0.31	0.02	0.25	0.38	0.99	< 0.01
	RES		0.41	0.58	0.18	0.39						
		Day	0.53[gh]	0.93[g]	0.16[h]							
SLC7A5	CON		0.30	0.46	0.15	0.30	0.14	0.72	0.43	0.26	0.81	0.57
	RES		0.24	0.13	0.25	0.21						
		Day	0.27	0.30	0.20							
SLC38A2	CON		0.18	0.51	0.50	0.40	0.13	< 0.01	0.96	0.37	< 0.01	0.20
	RES		0.09	0.42	0.68	0.39						
		Day	0.13[h]	0.46[g]	0.59[g]							
SLC38A7	CON		6.47	5.60	3.63	5.23	1.69	0.61	0.39	0.61	0.74	0.39
	RES		3.42	4.74	3.92	4.02						
		Day	4.95	5.17	3.77							

[1]Day of Gestation = number of days after insemination. Each gene expression is given as a fold change in relation to NB-NP level of expression set to 1.
[2]Probability values for effect of day, treatment and day × treatment on level of expression of individual genes. Probability values for the contrast of mRNA.
[3]Gene = *SLC1A1* and *SLC1A5* – solute carriers family 1, members 1 and 5. *SLC7A5* – solute carrier family 7, member 5. *SLC38A2* and *SLC38A7* – solute carriers family 38, members 2 and 7.
[4]CON = Heifers fed a diet that meets 100 percent of NRC requirements to gain 0.45 kg daily. RES = Heifers restricted to 60 percent of CON diet
[5]Mean level of expression across treatment within day and gene of interest.
[6]Average SEM for day × treatment interaction - day 16 CON n = 7, day 16 RES n = 7, day 34 CON n = 6, day 34 RES n = 9, day 50 CON n = 7, day 50 RES n = 7.
[7]Mean level of expression of treatment group across day of gestation within tissue and gene of interest.
[g-h]Means within row without a common superscript differ ($P \leq 0.05$).

ferentiation of the bovine conceptus at day 34 of gestation.

Data determined in this study aid in providing a more complete neutral and acidic AA transport profile in beef heifer uteroplacental tissues during early gestation. Such a transport profile would allow for future applied research involving supplementation of specific AA at specific points of early gestation.

This applied research may lead to strategic supplementation of AA, resulting in an increase in reproductive efficiency. An increase in reproductive efficiency would aid in achieving the producer's goal of one calf per cow per year and support the food demands of the growing world population.

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CHAPS 2020: Rewriting the Cow Herd Appraisal Performance Software (CHAPS)

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The NDSU Extension Service and North Dakota Beef Cattle Improvement Association developed the Cow Herd Appraisal Performance Software (CHAPS) as a herd management software for beef producers. Developed in MS-DOS in 1985 and rewritten for Windows in 2000, CHAPS is undergoing another rewrite to become CHAPS 2020. This user-friendly program will include easy data entry and movement between screens, and feature unique internal identification fields for each cow, calf and sire. Users will be able to store data from multiple herds under a single database. The improved-usability of CHAPS 2020 and accessibility of CHAPS data will continue to guide and improve beef herd management. We anticipate the release of CHAPS 2020 during the fall of 2017.

Summary

The Cow Herd Appraisal Performance Software (CHAPS) was developed as a herd management tool more than 30 years ago to help producers manage their herd data. CHAPS was developed in MS-DOS and rewritten for Windows in 2000, becoming CHAPS 2000. CHAPS 2000 is being rewritten as a browser-based, platform-independent application. CHAPS 2020 maintains the basics of CHAPS 2000, including producer data entry, with a new interface allowing easier movement among different stages of cow-calf production. Additionally, an internal identification field has been implemented to uniquely identify each sire, cow and calf among all CHAPS producers. CHAPS users with multiple herds will be able to store data from all herds in a single database in CHAPS 2020. The rewrite of CHAPS will improve the usability of CHAPS and make data more accessible. This will help producers and Extension professionals understand trends in beef production to manage their beef herds effectively. We anticipate the release of CHAPS 2020 during the fall of 2017.

Introduction

The NDSU Extension Service and North Dakota Beef Cattle Improvement Association (NDBCIA) developed Cow Herd Appraisal Performance Software (CHAPS) in 1985 as a beef herd management tool to collect, store and evaluate beef production data (Ringwall, 2004). For more than 30 years, the CHAPS team at the Dickinson Research Extension Center (DREC) has provided beef production benchmarks and industry standards for producers to gauge their herd performance (Ramsay et al., 2016).

CHAPS calculates individual herd means for overall calving distribution (heifers and cows), as well as separate calving distributions for heifers and cows. CHAPS also calculates herd mean reproductive percentages, including pregnancy, pregnancy loss, calving, calf death loss and weaning percentages, as well as culling and replacement percentages. Weight and growth benchmarks include herd mean birth and weaning weights, average daily gain (ADG) and weight per day of age (WDA), frame score, age at weaning, and cow age, weight and condition, as well as pounds weaned per cow exposed.

We have outlined calculations of reproductive and production benchmarks in this issue of the *North Dakota Beef Report* (Ramsay et al., 2017a); detailed benchmark calculations are described in Ramsay et al. (2017b, in press-a, in press-b). Yearly averages are calculated from herds with a minimum of 50 cows and three consecutive years of data submitted to the CHAPS program. Each year, the CHAPS team calculates five-year average benchmarks from the previous five yearly averages; for example, the 2017 benchmarks were determined by averaging 2012, 2013, 2014, 2015, and 2016 yearly data.

The CHAPS 2000 software needs to be rewritten to keep current with technology and meet the needs of beef producers. Features of the CHAPS rewrite include modifications to the existing program and beta testing performed by NDBCIA producers.

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Procedures

The CHAPS 2000 rewrite is a browser-based, platform-independent application based on the MySQL database and Apache Tomcat server. It maintains the basic functionality of the CHAPS 2000 program, allowing the producer to enter data for sires, cows and calves. The new interface allows the user to move a calf among the birth, weaning, background, replacement, feedlot and carcass stages with a single mouse click. Replacement calves move to cow or sire status with a single mouse click as well.

The rewrite includes extensive modifications to the CHAPS 2000 database. The single biggest change to the data model is the introduction of an internal identification field, the CHAPS-ID, which uniquely identifies each sire, cow and calf without interfering with the producer's own identification system. A CHAPS-ID will be unique across all CHAPS producers and will aid in birth-to-processing tracking and determining genealogy. When a sire, cow or calf moves between CHAPS producers, its CHAPS-IDs will follow it.

Additional changes to the database include the addition of a producer identification field and a herd identification field. The producer identification field allows data from all CHAPS producers to be stored in a single central database. When connected to the Internet, producers may submit their data to the central database with a single mouse click. The central database will serve as a cloud based data backup and aid in the generation of benchmark data. The herd identification field lets the producer maintain multiple herds and move cattle between herds using a single database while maintaining a historical record of movement.

To ensure CHAPS 2020 is working properly, virtual machines accessed via a remote desktop were used to test initial versions. CHAPS 2020 was tested with data from the DREC herd to ensure that the Herd Analysis report was correctly calculated. Several "test" herds were created and used to ensure that all management and cull codes were correctly handled. Beta testing with NDBCIA producers is scheduled for early fall of 2017.

Results and Discussion

When entering the CHAPS program, users see a welcome screen that provides summary information about the selected herd (Figure 1). From the welcome screen, the user can manage the selected herd, select a different herd or set up a new herd. Users may store data from multiple herds in a single database instead of setting up a new database for each herd.

Selecting the Cows tab provides a summary listing of cows in the herd (Figure 2). Filters allow the user to view active, culled and pedigreed cows, as well as specify birth ranges for the cows displayed. The user also can control the number of

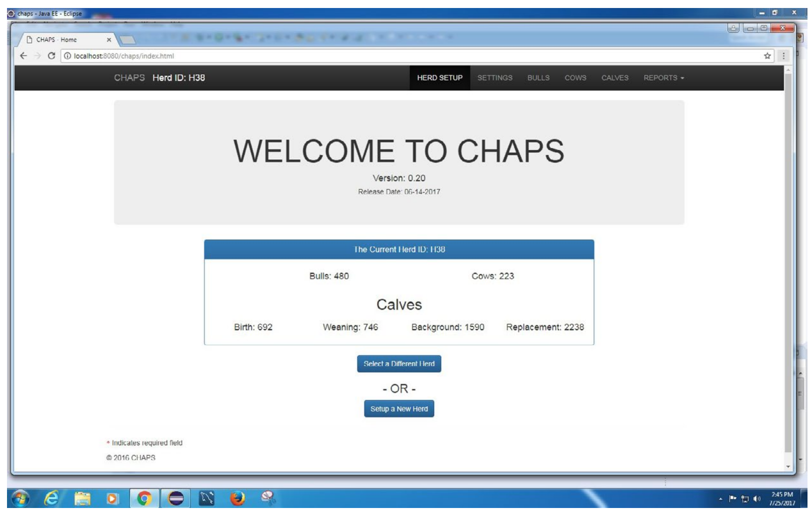

Figure 1. Welcome screen for CHAPS 2020 providing a summary of the herd selected, as well as options to select a different herd or set up a new herd.

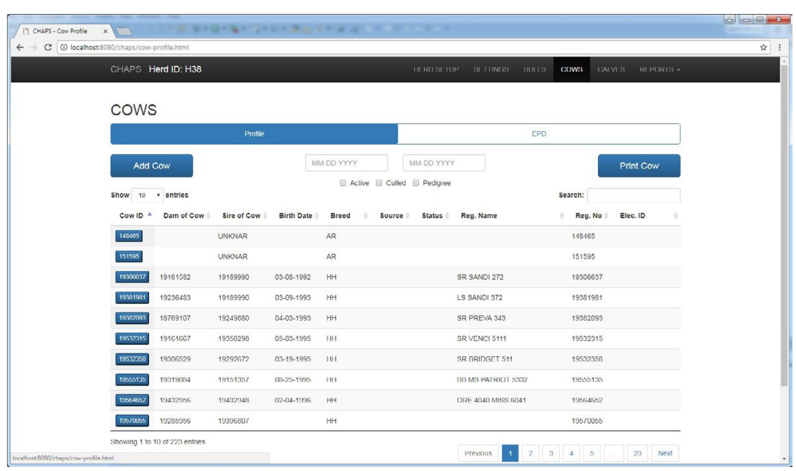

Figure 2. Example of Cows tab for CHAPS 2020 with a listing of cows in the herd.

cows presented on each page of the summary listing.

The Cow ID field is a clickable icon that opens an Edit Cow Profile window, allowing the user to edit cow data fields (Figure 3). The user has the ability to define up to 10 additional data fields for each cow.

Clicking the Add Cow icon opens an Add Cow Profile window that is similar to the Edit Cow Profile window. Cow ID, Birth Date, Breed and Sire are required fields when adding a new cow; a value of "Unknown" may be entered for Sire of Cow.

Clicking the Print Cow icon will open a new widow that displays the Cow Profile list in a PDF format (Figure 4). Selecting the Bulls tab provides the user with a summary listing of the bulls in the herd. The features of this tab are similar to the features found in the Cow tab.

Selecting the Calves tab allows the user to access the calf information (Figure 5). The calf information is stored in a stage model where each calf goes through a series of stages (birth, weaning, background or replacement, feedlot, carcass).

An Add Calf icon and clickable Calf ID icons provide the user with access to Add Calf and Edit Calf windows (Figure 6). Additional icons will allow the user to move a calf to a new stage with a single click. The system fills all of the appropriate data fields in the new stage entry, and a single click promotes a calf to a cow or bull.

The rewrite of CHAPS is an ongoing process. Ultimately, we plan to make historical CHAPS data accessible to animal scientists and Extension professionals to further support research into historical trends in beef production data (Ramsay et al., 2016). We anticipate the user-friendly format will be favorable to producers. We plan to release CHAPS 2020 during the fall of 2017.

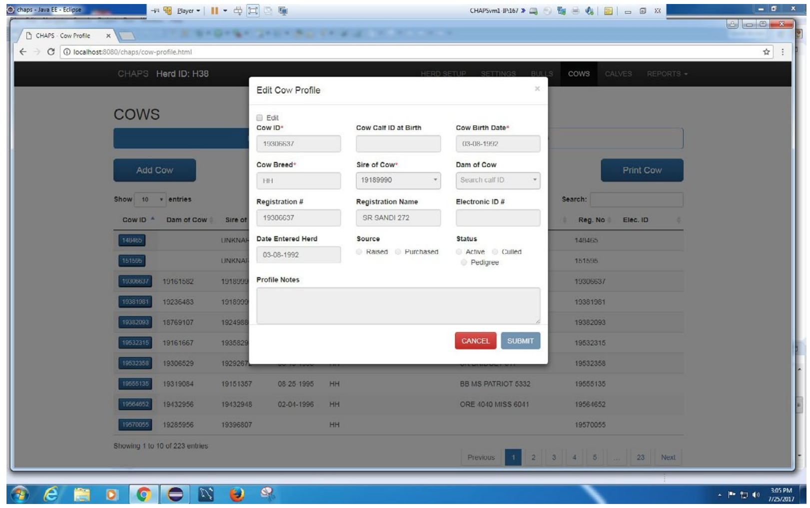

Figure 3. Example of Edit Cow Profile option for CHAPS 2020 with option to edit data fields.

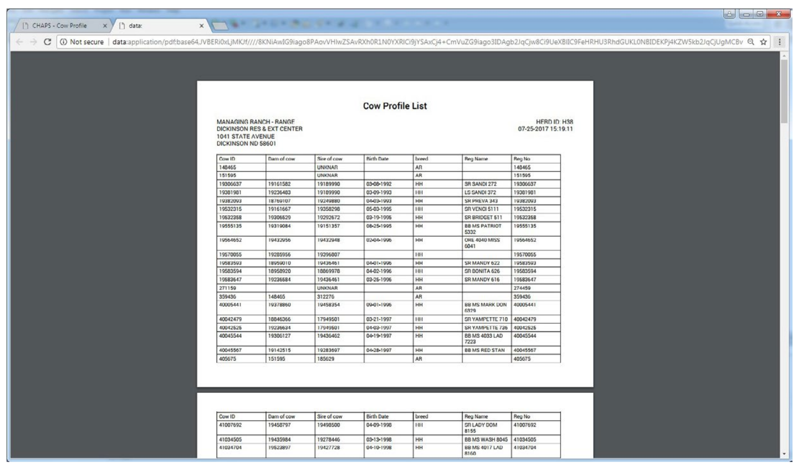

Figure 4. Example Cow Profile List generated by CHAPS 2020.

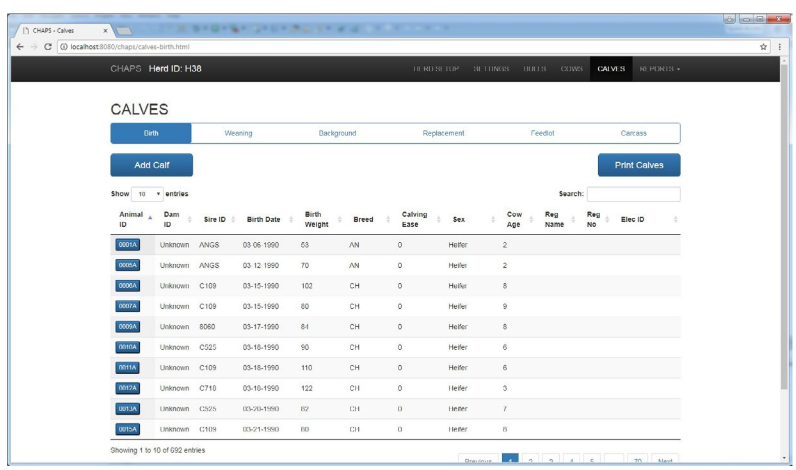

Figure 5. Example of Calves tab for CHAPS 2020 with a listing of calves in the herd.

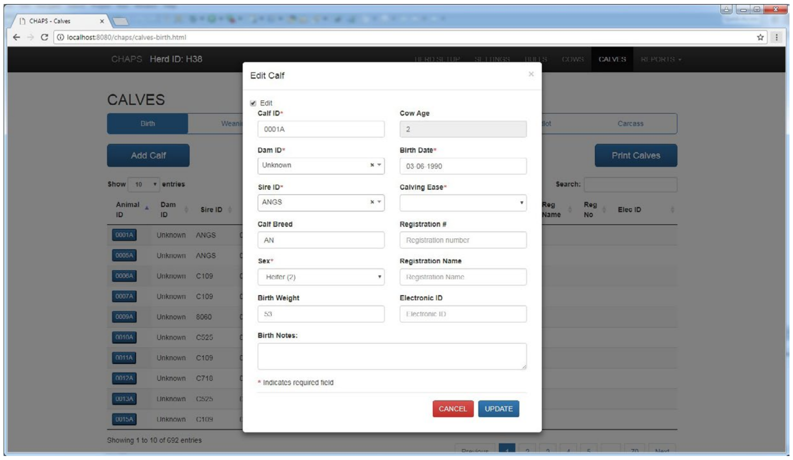

Figure 6. Example of the Edit Calf window for CHAPS 2020 with option to edit data fields.

Acknowledgments

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Cow Herd Appraisal Performance Software (CHAPS): 15 years of beef production benchmarks

Jennifer Ramsay[1], Lee Tisor[1], Lauren Hulsman Hanna[2] and Kris Ringwall[1]

Beef producers and Extension professionals have been using the Cow Herd Appraisal Performance Software (CHAPS) for more than 30 years to establish beef production benchmarks to help beef producers and Extension professionals set and achieve their management goals. Each year, the CHAPS team at the NDSU Dickinson Research Extension Center provides the beef industry with five-year benchmarks. We present historical CHAPS benchmarks (2003-2017). The benchmarks were relatively stable during the 15-year period. Improvements in calving distributions, pregnancy loss percentage, weaning percentage and age at weaning may be due to improvements in management, genetics and differences in breeds, as well as variation in the herds participating in the CHAPS program through time.

Summary

Beef producers and Extension professionals have used the Cow Herd Appraisal Performance Software (CHAPS) as a management tool since 1985, establishing benchmarks for the industry. Producers use CHAPS to calculate herd benchmarks, including herd calving distributions and reproductive percentages, as well as herd mean weights, growth and ages. Each year, the CHAPS team at the NDSU Dickinson Research Extension Center (DREC) receives herd data from producers and calculates yearly averages. From the yearly averages, the CHAPS team calculates five-year rolling average benchmarks. These standards help producers set herd goals and manage their herds to achieve their goals. We present historical CHAPS benchmarks from 2003-2017. In general, the benchmarks were stable during the 15-year period. Calving distributions improved from the initial benchmark years and then remained stable. Pregnancy loss percentages decreased and weaning percentages increased through time. Age at weaning decreased through time. Improvements in the benchmarks may be due to improvements in management, genetics and breed selection. Variation in the herds used in the CHAPS program also may have affected consistency of the benchmarks through time.

Introduction

The NDSU Extension Service and North Dakota Beef Cattle Improvement Association developed Cow Herd Appraisal Performance Software (CHAPS) as a beef herd management tool to collect, store and evaluate beef production data while establishing benchmarks for the industry (Ringwall, 2004; Ramsay et al., 2016). We have described the CHAPS program and its development in detail in Ramsay et al. (2014, 2016).

To review, CHAPS calculates individual herd calving distribution and reproductive percentages, including pregnancy, pregnancy loss, calving, calf death loss and weaning percentages, as well as culling and replacement percentages. CHAPS also calculates production benchmarks, including herd mean birth and weaning weights, average daily gain (ADG) and weight per day of age (WDA), frame score, age at weaning, and cow age, weight and condition, as well as pounds weaned per cow exposed.

From individual herd averages, yearly averages are calculated. Herds included in the yearly average calculation have a minimum of 50 cows and have submitted three consecutive years of data to the CHAPS program. Each year, the CHAPS team calculates five-year average benchmarks from the previous five yearly averages.

Errors in CHAPS datasets are identified and corrected using an established set of SAS procedures on a yearly basis (see Ramsay et al., 2014). Additionally, a 20-year (1994-2013) historical CHAPS dataset has been described (Ramsay et al., 2016); it has been used to evaluate yearly average calving distribution (Ramsay et al., 2017), reproductive percentages (Ramsay et al., in press-a), and weights and growth (Ramsay et al., in press-b) for that period.

In general, we found consistency through time for yearly averages. However, we found a greater variation among herd averages. We attributed some of this variation to differences in breeds, maternal ability at a given age, herd management and variable weather.

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The five-year benchmarks are the foundation of CHAPS and guide herd management decisions for CHAPS producers. Although NDSU reports the benchmarks annually on the CHAPS website (www.ag.ndsu.edu/DickinsonREC/chaps-software-1) and in *BeefTalk*, (Ringwall, 2016), we have not done a formal publication of historical benchmarks. Archived five-year benchmark data have been available only since 2003; therefore, we present historical CHAPS benchmarks (2003-2017) and discuss general trends in the data.

Procedures

Errors in CHAPS datasets were identified and corrected using an established set of SAS procedures on a yearly basis (see Ramsay et al., 2014). Each year, the CHAPS team generated production data from selected herds. Herds were selected if they have at least 50 cows and three years of data submitted to the program. From the production data generated, the CHAPS team calculated yearly averages. These yearly averages were stored with previous yearly averages to be used in subsequent five-year benchmark calculations.

Following calculation of the yearly averages, the CHAPS team calculated five-year benchmarks as an average of the previous five yearly values for each reproductive or production trait. For example, the 2017 benchmarks were determined by averaging 2012, 2013, 2014, 2015 and 2016 yearly data. We describe five-year benchmarks from 2003-2017, which were calculated from 1998-2016 yearly averages.

Benchmark data include calving distribution, which is defined as the percentage of dams calving during specific periods. The calving season starts when the third mature cow calves. CHAPS measures the overall percentage calving by 21 days, 42 days, 63 days and later (after 63 days) after the start of the calving season. Additionally, CHAPS measures early (prior to 21 days), 21-day and 42-day calving distributions for heifers (age = 2 years) and 21-day and 42-day calving distributions for mature cows (age more than 2 years). Early calving distributions are measured for heifers because the start of the calving season is based upon mature cows only.

Reproductive percentages measured by CHAPS include pregnancy, pregnancy loss, calving, calf death loss and weaning percentages, as well as culling and replacement percentages. Weight and growth benchmarks are reported in pounds and include birth and weaning weights, ADG, WDA, frame score, age at weaning (days) and cow age (years), weight and condition, as well as pounds weaned per cow exposed. Calculations of each reproductive and production trait have been described previously (Ramsay et al., 2017, in press-a, in press-b).

Results and Discussion

Data were derived from approximately 275,000 cow exposures to bulls from 1998 to 2016, with almost 15,000 cows exposed to bulls each year. On average, 60 herds per year were used in calculating the benchmarks.

During the 19-year period, data from 166 herds were used to calculate yearly averages. Of these herds, 64 had one to three years of data, most of which were from 1998 to 2000. Eighteen herds had data for the entire period, from 1998 to 2016. More than half of the herds had six years of data or less. One-third of the herds had 10 years of data or more. Breeds varied among herds, with Angus, Red Angus, Hereford, Charolais, Limousin, Gelbvieh and Lowline predominating.

Five-year benchmarks for calving distribution (Table 1), reproductive percentages (Table 2), weights and growth for calves (Table 3) and cows (Table 4) are presented.

The benchmarks were stable during the 15-year period, with some improvements through time.

Table 1. Five-year benchmarks of overall calving distributions (at 21 days, 42 days, 63 days and after 63 days) and calving distributions for heifers (prior to 21 days – early, 21 days and 42 days), and cows (21 days and 42 days) from 2003 to 2017. All calving distributions are expressed in percentages.

	Overall				Heifers			Cows	
Year	21 d	42 d	63 d	>63 d	early	21 d	42 d	21 d	42 d
2003	60	85	94	6	34	69	85	57	84
2004	61	86	94	6	36	71	85	58	85
2005	62	86	95	5	35	71	85	60	85
2006	64	88	96	4	35	71	85	61	87
2007	64	88	96	4	34	71	84	63	87
2008	64	89	96	4	36	72	85	63	87
2009	64	88	96	4	36	71	84	64	86
2010	64	88	96	4	38	72	85	63	86
2011	63	88	95	5	37	72	86	61	85
2012	63	88	96	4	38	73	87	60	85
2013	63	88	96	4	36	72	86	60	86
2014	63	88	96	4	37	73	87	59	86
2015	62	87	96	4	37	72	86	59	86
2016	63	87	96	4	38	74	86	60	87
2017	63	87	96	4	39	74	86	60	87

Calving distributions improved from the initial period (2003-2006) and then remained stable. The pregnancy loss percentage decreased and the weaning percentage increased through time. Age at weaning also decreased through time. Ringwall (2015) has noted that consistency of the benchmarks is a hallmark of the beef business and that improvements are likely due to improvements in management and genetics. Some of these improvements also may be due to differences in breeds or the consistency of herds through time.

We plan to investigate these factors in future analyses of historical CHAPS data. The consistency of the CHAPS benchmarks through time continues to act as a solid foundation to guide herd management and the future of the beef industry.

Table 2. Five-year benchmarks for pregnancy, pregnancy loss, calving, calf death loss, weaning, replacement and culling percentages from 2003 to 2017.

Year	Pregnancy	Pregnancy Loss	Calving	Calf Death Loss[1]	Calf Death Loss[2]	Weaning	Replacement	Culling
2003	93.4	0.7	92.8	3.1	3.3	90.3	16.9	14.4
2004	93.5	0.7	92.8	3.2	3.4	90.2	15.8	14.7
2005	93.4	0.7	92.8	3.1	3.3	90.3	15.1	13.8
2006	93.4	0.8	92.7	3.1	3.4	90.3	14.8	14.0
2007	93.7	0.7	93.0	3.1	3.2	90.9	14.7	14.7
2008	93.5	0.7	92.8	3.0	3.2	90.8	15.0	14.6
2009	93.7	0.7	93.1	3.0	3.1	91.1	14.9	14.2
2010	93.8	0.7	93.1	3.1	3.4	91.1	15.2	13.9
2011	93.7	0.7	93.1	3.2	3.6	90.9	15.3	13.7
2012	93.5	0.7	92.8	3.2	3.7	90.5	15.6	13.9
2013	93.6	0.7	93.0	3.3	3.8	90.7	15.3	13.5
2014	93.5	0.7	92.9	3.4	3.9	90.4	15.6	13.6
2015	93.5	0.6	92.9	3.4	3.7	90.4	15.2	13.2
2016	93.7	0.6	93.0	3.3	3.6	90.5	14.9	13.2
2017	93.8	0.5	93.3	3.2	3.4	91.0	14.7	13.2

[1]relative to the number of exposed females
[2]relative to the number of calves born.

Acknowledgments

We thank Wanda Ottmar and Michele Stolz for management of the CHAPS data. We also thank Philip Berg, Keith Helmuth and Madonna Tibor for their development and management of the CHAPS software and past analysis of the CHAPS data.

Table 3. Five-year benchmarks of calf weights, ages and growth. Weights and growth are measured in pounds and ages are measured in days.

Year	Birth Weight	Age at Weaning	Weaning Weights: All	Steer	Heifer	Bull	Adjusted 205-day	ADG[1]	WDA[2]	Frame Score
2003	83	196	558	566	539	607	613	2.3	2.9	5.4
2004	87	194	556	558	542	612	618	2.4	2.9	5.4
2005	88	192	558	562	545	618	627	2.5	3.0	5.4
2006	88	191	562	567	548	622	634	2.5	3.0	5.5
2007	88	189	561	566	546	621	636	2.5	3.0	5.5
2008	87	189	560	565	545	615	637	2.5	3.0	5.8
2009	87	189	567	573	544	616	640	2.5	3.0	5.8
2010	86	189	565	574	546	610	637	2.5	3.0	5.8
2011	86	189	563	572	545	604	636	2.5	3.0	5.8
2012	86	190	563	572	547	607	633	2.5	3.0	5.7
2013	85	190	558	571	545	602	630	2.5	3.0	5.7
2014	84	192	556	571	542	595	623	2.5	2.9	5.5
2015	83	192	555	567	537	595	620	2.5	2.9	5.4
2016	83	193	553	565	534	593	617	2.5	2.9	5.2
2017	82	192	554	568	535	593	620	2.5	2.9	5.2

[1]average daily gain = (weaning weight – birth weight)/calf age.
[2]weight per day of age = weaning weight/calf age.

Table 4. Five-year benchmark of cow weights and ages, as well as pounds weaned per cow exposed. Weights are measured in pounds and ages are measured in years.

Year	Cow Age	Cow Weight	Cow Condition	Pounds Weaned Per Cow Exposed
2003	5.4	1,357	5.3	501
2004	5.5	1,354	5.3	498
2005	5.6	1,378	5.4	500
2006	5.6	1,407	5.6	502
2007	5.7	1,413	5.7	502
2008	5.7	1,395	5.7	500
2009	5.7	1,408	5.7	507
2010	5.7	1,400	5.7	505
2011	5.7	1,396	5.7	503
2012	5.6	1,398	5.8	501
2013	5.6	1,421	5.9	499
2014	5.6	1,418	5.9	496
2015	5.6	1,411	5.8	495
2016	5.6	1,399	5.7	494
2017	5.6	1,398	5.6	498

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Stockpiled grass and crop-residue grazing reduce cow wintering cost

Songül Şentürklü[1,2] and Douglas Landblom[1]

The objective of this study was to determine the potential for reducing gestating cow winter feed costs for cows calving in May-June who are grazing cover crops, corn and sunflower residues, or stockpiled improved grass and corn residue. Supplementing cows with a pelleted dried distillers grain with solubles (DDGS)-based protein-energy supplement extended the grazing of low-quality forages, increased grazing days and reduced the amount of hay fed. Compared with feeding hay, grazing stockpiled improved-grass forages followed by corn residue reduced wintering cost 2.8 times ($135.48/cow). The wintering method did not affect reproductive performance.

Summary

A two-year (2013-2014), 134-day cow wintering experiment was designed to evaluate gestating cow overwintering methods and cost. One hundred forty-four 3- to 10-year-old May-June calving crossbred cows were used in the study (three treatment replicates, eight cows/replicate). A control (C) group of cows received hay only in dry-lot pens. Compared with the C group, one group grazed a seven-species cover crop followed by corn and sunflower residues (CC-RES) and a second group grazed stockpiled improved grass followed by corn stalk residue (GRAS-RES). Cows in all treatments received 1.74 pounds dry matter (DM) of a 32 percent crude protein (CP) supplement ($339.25/ton). After grazing approximately 50 to 60 percent of the available low-quality residue or stockpiled grass, the cows received hay until the study ended in April. Overall, total gain during the 134-day wintering period for the C, CC-RES and GRAS-RES treatments was 205, 146 and 112 pounds, respectively. Body condition scores (BCS) for the C and CC-RES cows increased 0.79 and 0.71 of a condition score/cow, respectively (P = 0.05), but the GRAS-RES group's BCS did not change (5.4). Reproductively, subsequent calving percentage was not influenced by treatment for the first (P = 0.12), second (P = 0.15) and third (P = 0.26) calving cycles, percent of nonpregnant cows (P = 0.47) and total percent calving (P = 0.46). The overwintering cost for the three methods compared was markedly different. Hay cost/cow for the C, CC-RES and GRAS-RES was $172.51, $67.74 and $29.94/cow, respectively (P = 0.001). Accounting for supplement, farming and tax expenses, the total wintering cost for the C, CC-RES and GRAS-RES was $208.81, $140.59 and $73.33/cow, respectively. On a calendar year basis, C, CC-RES and GRAS-RES cows grazed 7.6, 10 and 11.1 months of the year, respectively. However, producers considering winter grazing should proceed cautiously because North Dakota winters are unpredictable and harsh. We suggest they have enough hay on hand for one, and preferably two, years as a precaution for weather conditions that pre-empt winter grazing.

Introduction

Beef cattle production costs for harvested and grazed forages, grain, coproducts and commercial supplements constitute the majority of cattle ranching expenses (Lardy and Caton, 2010). Feeding harvested and processed feeds are more expensive than grazing forages directly. North Dakota farmers and ranchers grow corn, sunflowers and cover crops that are suitable low-quality forages for grazing by nonlactating, gestating cows after weaning.

Stockpiled improved grasses (brome- and crested wheatgrass) also are suitable low-quality forage sources. Cline et al. (2009) documented that the nitrogen (N) content of mixed-grass prairie grazed by cattle in western North Dakota declined after September and, with advancing season, improved grasses decline as well.

The metabolizable protein system divides feed protein fractions into rumen-degradable (DIP) and undegradable protein (UIP) (National Research Council, 1996). For low-quality forage, the response to increasing levels of supplemental protein is variable; however, the DIP fraction is responsible for increased forage organic-matter intake and digestion (Hollingsworth-Jenkins, et al., 1996; Olson et al., 1999; Mathis et al., 2000). Grazing crop residues and

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stockpiled grasses with supplemental protein represents opportunities to extend the grazing season and potentially reduce cow overwintering feed cost.

A diverse crop rotation consisting of spring wheat, cover crops, corn, field-pea, barley and sunflowers grown at the Dickinson Research Extension Center was a source for corn and sunflower residue, as well as stockpiled improved grasses for this extended winter grazing investigation.

The objective of the two-year study was to evaluate three winter feeding methods for nonlactating, gestating beef cows during the late-fall and winter period from November to April to determine total grazing days, cow weight change, body condition score change, post-wintering reproductive performance and wintering method economics.

Experimental Procedures

The North Dakota State University Institutional Animal Care and Use Committee approved research procedures used in this study.

One hundred forty-four 3- to 10-year-old May-June calving crossbred cows (three treatment replicates, eight cows/replicate) were used in the 134-day study to evaluate gestating cow overwintering methods and cost.

Cover crop and crop residues grazed were grown as sequence crops in an integrated crop and beef cattle study in which yearling steers grazed unharvested corn before the wintering study and sunflowers were combined for oilseed. For the CC-RES treatments, the residues and seven-species cover crop consisted of warm- and cool-season annuals. Table 1 describes the seven-species cover crop blend, pounds/acre seeded, cost/acre and grazing cost/cow.

The stockpiled GRAS-RES treatment consisted of perennial improved grasses (bromegrass and crested wheatgrass) and forage corn residue. Control cows received hay in dry-lot pens after weaning until the end of the study in April. Nutri-

Table 1. Seven-species cover crop blend, cost/Ac and grazing cost/cow.

Crop Blend	lb/Ac	Cost/lb, $	Cost/Ac, $
Sunflower	2	4.50	9.00
Everleaf oat - 114	20	0.37	7.40
Winter pea	20	0.40	8.00
Hairy vetch	5	1.75	8.75
Winfred forage rape	1	3.50	3.50
Ethiopian cabbage	1	4.00	4.00
Hunter leaf turnip	1	3.50	3.50
Total seed cost/Ac, $			44.15
Farming cost and property tax/Ac, $			23.85
Cover crop cost/Ac, $			68.00
Grazing cost/cow, $			36.55

Table 2. Nutrient analysis of stockpiled improved grasses and annual forage crop residue.

	CP (%)	NDF (%)	ADF (%)	Fat (%)	IVDMD (%)	IVOMD (%)	Ca (%)	Phos (%)	TDN (%)
Stockpiled Brome and Crested Wheatgrass									
Start (Nov. 6)	7.1	75.0	44.6	1.20	41.1	39.9	0.34	0.20	48.2
Mid (Dec. 22)	5.6	80.9	50.4	0.41	34.1	32.7	0.28	0.18	43.6
End (Jan. 15)	5.0	83.6	52.9	0.82	30.8	29.2	0.34	0.11	41.6
Cover Crop									
Start (Nov. 18)	12.3	32.8	20.5	1.03	82.9	82.3	0.97	0.33	67.4
End (Dec. 15)	12.9	54.9	36.8	0.86	62.3	61.5	1.26	0.25	54.5
Corn Stalk Residue									
Start (Dec. 15)	5.4	70.3	41.7	0.67	60.0	59.8	0.25	0.17	51.3
End (Dec. 29)	4.7	74.6	43.7	0.39	51.0	49.5	0.32	0.14	49.4
Corn Trash Residue on Ground									
Start (Dec. 15)	7.0	58.4	29.8	1.43	66.7	67.4	0.16	0.23	60.9
End (Dec. 29)	5.0	74.7	43.6	0.58	49.8	48.5	0.29	0.12	49.6
Sunflower Residue (Combine)									
Start (Dec. 29)	5.9	58.0	44.3	4.50	54.2	49.7	1.37	0.16	48.4
End (Jan. 20)	4.0	76.6	58.1	0.44	34.7	28.6	1.17	0.07	37.5

ent analysis for starting and ending stockpiled grass, cover crop and annual forage residues are summarized in Table 2.

Grazing treatment cows (CC-RES and GRAS-RES) grazed their respective annual forage residues, or stockpiled grass, until 50 to 60 percent removal and then transferred to dry-lot pens, where they were fed hay until the end of the study. Cows in all treatments received an average of 1.74 pounds (DM) of a 32 percent crude protein (CP) dried distillers grain with solubles supplement daily ($339.25/ton, as fed) based on the average starting weight of all cows in the study (0.12 percent of body weight [BW]).

Cow weight and visual BCS were determined at the start and end of the study. The breeding season for the May-June calving cows started Aug. 10 each year and calving began approximately May 20. The effect of the wintering treatment on calving cycle, nonpregnant cows and total percent of cows calving was determined during the subsequent calving season.

For comparative cost analysis, all annual forage crop expenses were charged to the previous enterprises (cropping and yearling steer grazing) and land was considered to be owned. The hay price was $65/ton (as fed). The only direct farming expenses incurred were for cover-crop production in the CC-RES treatment and the Dunn County, N.D., property tax, which was included for both grazing treatments. Data analysis conducted using the MIXED procedure of SAS.

Results and Discussion

Table 3 summarizes cow weight fluctuations and BCS change for the periods when CC-RES and GRAS-RES cows grazed cover crops, grass and residues. Grazing length was greatest for the GRAS-RES (107 days), compared with the CC-RES cows (73 days), because the grazing goal was to remove only 50 to 60 percent of the grass residue in the stockpiled grass treatment. Therefore, GRAS-RES had twice as many acres of forage to graze before grazing corn residue.

Comparing cow performance during the grazing period (CC-RES, 73 days; GRAS-RES, 107 days), CC-RES cows gained less than the GRAS-RES cows ($P = 0.001$); however, body condition score at the end

Table 3. Cow winter grazing and dry lot weight and condition score change.

	CC-RES[1]	GRAS-RES[1]	SEM[2]	*P* - Value[3]		
				Trt	Yr	Trt x Yr
Grazing						
Number of cows	48	48				
Number of days grazed	73	107				
Start weight, lb.	1,500	1,470	59.61	0.36	0.24	0.24
End weight, lb.	1,518	1,536	42.3	0.58	0.29	0.94
Gain, lb.	18.0[a]	66.0[b]	19.12[c]	0.001	0.84	0.003
ADG, lb.	0.25[a]	0.62[b]	0.19[c]	0.001	0.40	0.001
BCS						
Start BCS	5.6	5.4	0.16	0.10	0.006	0.94
End BCS	5.5	5.2	0.16	0.15	0.51	0.46
BCS change	-0.10	-0.20	0.11	0.76	0.05	0.29
Dry lot - Hay						
Number of cows	48	48				
Number of days fed hay	61	27				
Start weight, lb.	1,518	1,536	42.3	0.58	0.29	0.94
End weight, lb.	1,646	1,582	46.5	0.06	0.90	0.84
Gain, lb.	128[a]	46[b]	5.58[c]	0.001	0.001	0.21
ADG, lb.	2.10	1.70	0.25	0.18	0.40	0.53
BCS						
Start BCS	5.5	5.1	0.15	0.13	0.58	0.52
End BCS	6.3	5.4	0.14	0.001	0.60	0.45
BCS change	0.80	0.30	0.088	0.001	0.69	0.009

[1]CC-RES: Cover crop and residue (corn and sunflower), GRAS-RES: stockpiled grass and corn residue.
[2]SEM: Pooled standard error of the mean.
[3]*P*-Values: Trt; (treatment), Yr; (year), and Tr x Yr; (treatment x year interaction).
[a-c]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).

of grazing was similar for the two grazing groups ($P = 0.76$).

In dry lot after grazing, the CC-RES cows received hay for 61 days, compared with the GRAS-RES cows that received hay for 27 days. During the 61-day period on hay, BCS for the CC-RES cows increased from the end of residue grazing to the end of the wintering study. On a calendar year basis, C, CC-RES and GRAS-RES cows grazed 7.6, 10 and 11.1 months of the year, respectively.

Overall, total gain during the 134-day wintering period for the C, CC-RES and GRAS-RES treatments was 205, 146 and 112 pounds, respectively (Table 4). Body condition score change for the C and CC-RES were 0.79 and 0.71 of a full condition score/cow, respectively, which was significantly greater than the GRAS-RES condition score, which did not change during the wintering period ($P = 0.05$). Although C and CC-RES cows' BCS increased, GRAS-RES cows' BCS of 5.4 remained the same from the beginning to the end of the study.

The percent of cows calving in the first through third calving cycles, percent open and the total percent calving established the basis for reproductive performance (Table 5). We found no differences measured for the first ($P = 0.12$), second ($P = 0.15$) and third ($P = 0.26$) calving cycles, percent of nonpregnant cows ($P = 0.47$) and the total percent calving ($P = 0.46$).

Because May-June calving cows calve on lush spring grass and the breeding season did not begin until Aug. 10, grazing nutrition and environmental conditions supported reproductive efficiency. The amount of low-quality forage grazed during the third trimester of pregnancy is reduced because later-calving cows graze spring forage before and during calving (April-June).

Expenses for the three wintering methods were markedly different (Table 6). Hay cost/cow for the C, CC-RES and GRAS-RES was \$172.51, \$67.74 and \$29.94/cow, respectively ($P = 0.001$). Combining expenses for supplement, hay, cover crop (seed, farming and property tax) and stockpiled grass on owned land (property tax), the total wintering cost for the C, CC-RES and GRAS-RES was \$208.81, \$140.59 and \$73.33/cow, respectively. Comparing the wintering cost of the C cows with the CC-RES cows, the reduction was \$68.22/cow, and comparing with the GRAS-RES cows, the overwintering cost reduction was \$135.48/cow, or 2.8 times less (\$208.81 ÷ \$73.33).

Replacing hay feeding with supplemented low-quality forage and stockpiled grass grazing reduces winter feed costs, labor, fuel, maintenance and repair, and improves quality of life without negatively affecting reproductive performance. Producers should be cautious, however, because any extended winter grazing program

Table 4. Combined grazing and dry lot hay feeding effect on weight and condition score change.

	C[1]	CC-RES[1]	GRAS-RES[1]	SEM[2]	*P* - Value[3]		
					Trt	Yr	Trt x Yr
Number of cows	48	48	48				
Total winter feeding days	134	134	134				
Start weight, lb.	1,490	1,500	1470	59.8	0.62	0.15	0.40
End weight, lb.	1.695	1,646	1582	47.1	0.87	0.58	0.55
Gain, lb.	205[a]	146[b]	112[c]	17.3	0.001	<0.007	<0.001
ADG, lb.	1.53[a]	1.10[b]	0.84[c]	0.13	0.002	0.23	<0.001
Hay and Supplement (DM)							
Hay/cow, lb.	4.724.0[a]	1,824.0[b]	891.0[c]	44.33	<0.001	<0.001	<0.001
Hay/cow/day, lb.	35.3	30.6	33.1	0.47	0.40	<0.001	0.002
32% CP suppl./cow, lb.	214.0	214.0	214.0				
32% CP suppl./cow/day, lb.	1.74	1.74	1.74				
BCS							
Start BCS	5.7	5.6	5.4	0.25	0.57	0.008	0.93
End BCS	6.5	6.3	5.4	0.21	0.38	0.10	0.30
BCS change	0.79[a]	0.71[a]	0.0b	0.15	0.05	0.15	0.49

[1]C: Control (dry lot hay), CC-RES: cover crop and residue (corn and sunflower), GRAS-RES: stockpiled grass and corn residue.
[2]SEM: Pooled standard error of the mean.
[3]*P*-Values: Trt; (treatment), Yr; (year), and Tr x Yr; (treatment x year interaction).
[a-c]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).

must have a backup plan for harsh winter weather. Blizzards and deep snow are impediments to grazing and the only alternative is to feed hay. Extended winter grazing conserves hay, but having one to two years' reserve hay supply on hand is essential insurance when weather impedes grazing.

Acknowledgments

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Table 5. Cow wintering treatment effect on calving cycle and total calving percent.

	C[1]	CC-RES[1]	GRAS-RES[1]	SEM[2]	*P* - Value[3] Trt	Yr	Trt x Yr
Number of cows	48	48	48				
First calving cycle, %	72.6	69.3	60.5	3.92	0.12	0.005	0.035
Second calving cycle, %	10.4	23.8	20.8	4.66	0.15	0.18	0.52
Third calving cycle, %	6.3	2.1	8.3	2.79	0.26	0.004	0.27
Open, %	10.7	4.8	10.4	3.70	0.47	0.45	0.48
Total calving, %	89.3	95.2	89.6	3.70	0.46	0.44	0.47

[1]C: Control (dry lot hay), CC-RES: cover crop and residue (corn and sunflower), GRAS-RES: stockpiled grass and corn residue.
[2]SEM: Pooled standard error of the mean.
[3]*P* - Values: Trt; (treatment), Yr; (year), and Tr x Yr; (treatment x year interaction).

Table 6. Cow wintering treatment effect on feed intake and winter-feeding method economics (owned land).

	C[1]	CC-RES[1]	GRAS-RES[1]	SEM[2]	*P* - Value[3] Trt	Yr	Trt x Yr
Economics							
Days hay fed	133.5	61.0	27.0				
Days grazing	0.0	73.0	107.0				
Hay cost/cow, $	172.51^{a}	67.74^{b}	29.94^{c}	1.62	0.001	0.001	0.001
32% CP suppl cost/cow, $	36.30	36.30	36.30				
Cover crop cost/cow, $	–	36.55	–				
Total winter feeding Cost/cow, $[4]	208.81^{a}	140.59^{b}	73.33^{c}	1.9	<0.001	<0.001	<0.008

[1]C: Control (dry lot hay), CC-RES: cover crop and residue (corn and sunflower residues), GRAS-RES: stockpiled grass and residue (corn residue).
[2]SEM: Pooled standard error of the mean.
[3]*P*-Values: Trt; (treatment), Yr; (year), and Tr x Yr; (treatment x year interaction).
[a-c]Means with different superscripts within a line are significantly different, ($P \leq 0.05$).
[4]Grazing treatments include Dunn County, N.D., property tax.

Winter feeding strategies: Implications of corn supplementation on calf performance

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Maternal nutrient restriction in gestating beef cows is common during winter months and can lead to compromised offspring fertility and carcass quality. We examined the implications of supplementing corn during mid to late pregnancy on birth parameters and found that corn supplementation offered limited advantage to the neonate if forage was not limited. However, if forage cannot be supplied to meet the dam's nutritional requirements, then corn supplementation is effective at preventing the negative impacts observed in nutrient-restricted beef cows.

Summary

The objective of this study was to evaluate the effects of supplementing low-quality forage with corn to gestating beef cows by examining birth parameters and neonatal performance. We hypothesized that mid- to late-gestating beef cows receiving corn supplementation would have increased placental vascularity and size, and increased colostrum production, and give birth to faster-growing calves. Forty-seven Angus beef cows carrying bull calves were assigned randomly to treatments receiving corn supplementation at 0.2 percent of body weight (SUP; n = 24) or no supplement (CON; n = 23). All cows were fed the same low-quality forage basal diet throughout mid to late pregnancy. At birth, body weights of the cow and calf, colostrum samples and placental tissues were collected. The calves again were weighed three weeks after birth and at weaning (day 168). At birth, colostrum production ($P = 0.64$) and placental weight measurements ($P > 0.20$) were not altered by maternal corn supplementation. However, placental vascular surface density ($P < 0.01$) was suppressed by maternal corn supplementation. While calf birth weights were not altered by maternal corn supplementation ($P > 0.50$), calves from SUP dams were heavier at three weeks postpartum ($P = 0.05$) but not at weaning ($P > 0.60$). Corn appears to be a good substitute for hay if resources are limited to help maintain normal calf growth.

Introduction

Inadequate maternal nutrition during pregnancy can lead to a decrease in carcass quality of the offspring, including altered fat deposition, muscle fiber type and reduced meat quality (Wu et al., 2006). In fact, offspring of dams that were protein-restricted during late pregnancy had reduced feedlot performance and intramuscular fat accretion (Stalker et al., 2006).

Unfortunately, nutrient restriction still is common in extensively managed, overwintered, gestating beef cows due to limited access to high-quality forage. Nutrient restriction can be resolved by improving the forage quality of cows during late gestation, but if that feed resource is not available, an alternate feeding strategy should be employed.

We hypothesized that mid- to late-gestating beef cows receiving corn supplementation would have increased placental vascularity and size, and increased colostrum production, and give birth to faster-growing calves. The objectives of this study were to evaluate the effects of corn supplementation in gestating beef cow on feed placental characteristics, colostrum production and neonatal performance and growth.

Experimental Procedures

All procedures were approved by the North Dakota State University Animal Care and Use Committee (IACUC #A16010). Forty-seven beef cows (predominately Angus breeding) carrying bull calves from the Central Grasslands Research Extension Center (CGREC) near Streeter, N.D., were transported to the Beef Cattle Research Complex in Fargo, N.D.

The cows were assigned randomly to treatments (CON; n = 23) receiving ad libitum access to a low-quality forage-based diet only (57.54 percent total digestible nutrients [TDN], 6.4 percent crude protein [CP]) or (SUP; n = 24) an additional corn supplement at 0.2 percent of body weight. Cows weighed 1457 ±

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17.2 kg, had a body condition score of 5.2 ± 0.1 (9-point scale) and were 7.5 ± 0.2 years old at the start of the study.

Dietary treatments began on day 100 of gestation and lasted for 22 weeks. At day 265 of pregnancy, all cattle were fed a common lactation diet (45 percent straw, 30 percent corn silage and 25 percent dried distillers grains with solubles [DDGS]) that was higher in protein (11.6 percent CP) until three weeks postpartum.

Calving was monitored continuously from day 265 of gestation until all calves were born. Immediately after calving, the pairs were brought into the barn for monitoring and health analysis. Placental, back right quarter-colostrum and calf measurements were recorded at birth. Calf body weight was determined at birth, 24 hours and three weeks postpartum and at weaning (168 ± 16 days postpartum).

After weighing, representative cotyledons were processed and fixed in formalin for histological preparation. Fixed cotyledons were embedded in paraffin, sectioned at 5-micrometer (μm) intervals and stained with hematoxylin and eosin. Four representative images were taken of each sample at 20x magnification with an Axio Imager.M2 microscope and AxioVision 4.8 software (Carl Zeiss International, Jena, Germany). Image analysis was performed using the Image-Pro Premier 9.2 software package (Media Cybernetics Inc., Rockville, Md.).

At least three randomly chosen polygons were drawn in each image to determine vascular area density (VAD, % = vascular area/tissue area; a blood flow-related measure) and vascular surface densities (VSD, vascular area in μm^2/tissue volume in μm^3; a nutrient exchange-related measure) as described by Borowicz et al. (2007). Total vascular volume in milliliters (mL) was calculated as VAD × total cotyledonary weight (g), assuming that VAD is equivalent to vascular volume density (Borowicz et al., 2007).

All measurements and data collected were analyzed with generalized least squares mixed procedure of SAS (SAS Institute, Cary, N.C.), with repeated measures using least squares. Model statements included cow, maternal diet (CON vs. SUP), day of gestation and a diet by day of gestation interaction. Sire was treated as a random variable. All meaningful interactions were considered and in the absence of interactions, main effects were discussed.

Results and Discussion

We found corn supplementation reduced ($P < 0.001$) roughage intake by SUP cows; however, the TDN consumed tended to be greater in SUP cows ($P = 0.06$) because of the energetically dense corn that substituted for the lost roughage intake by SUP cows. We found a day by treatment interaction (P < 0.01) for body weight and body condition because SUP cows gained body weight and condition faster than control cows.

At parturition, calf birth weights (87.7 vs. 87.3 ± 2.21 pounds) were unaffected ($P = 0.50$) by maternal corn supplementation, with calves from SUP dams being like calves from CON cows at birth. Additionally, calf heart girth (31.5 vs. 31.9 ± 0.30 inches) and crown-rump length (34.2 vs. 33.1 ± 1.69 inches) at birth also were not influenced ($P \geq 0.20$) by maternal diet.

Interestingly, the SUP cows tended ($P = 0.07$) to have shorter gestation lengths (278 vs. 280 ± 1 day), with no difference ($P = 0.50$) in incidence of dystocia, compared with CON cows. Corn supplementation did not influence ($P = 0.64$) colostrum production (22.3 vs. 24.9 ± 3.89 ounces) because SUP vs. CON dams produced similar quantities of colostrum from their back-right quarter.

Placental measures collected at birth were similar ($P > 0.20$) across treatments for total placental weights (9.4 vs. 9.8 ± 0.62 pounds), total cotyledon number (80 vs. 91 ± 18) and total cotyledonary weight (3.5 vs. 3.8 ± 0.26 pounds). Furthermore, no differences ($P > 0.50$) in intercotyledonary weight (4.7 vs. 5.0 ± 0.35 pounds) or largest cotyledon weight (2.9 vs. 3.0 ± 0.25 ounces) were found.

However, maternal diet did alter the size of the smallest cotyledon weight, with SUP cows having a larger ($P = 0.04$) smallest cotyledonary weight than CON cows (0.03 vs. 0.01 ± 0.01 ounces). Interestingly, SUP cows tended to have decreased ($P = 0.10$) cotyledonary VAD (10.77 vs. 8.90 ± 1.01 percent; Figure 1), compared with CON cows. Additionally, SUP cows had decreased ($P < 0.01$) cotyledonary VSD (1,024 vs. 627 ± 97 $\mu m^2/\mu m^3$; Figure 1), compared with CON cows. However, total vascular volume was not altered ($P > 0.20$) by dietary treatment (190.3 vs. 165.6 ± 24.3 mL).

Similar to measurements at parturition, 24-hour calf body weights also were not altered ($P = 0.68$) by maternal diet, with calves from corn-fed dams weighing similarly to offspring from hay-fed cows (88.2 vs. 89.3 ± 4 pounds). At three weeks after calving, calves from SUP dams were heavier ($P = 0.05$) than calves from CON dams (159.8 vs 151.9 ± 7.72 pounds). However, this effect disappeared by weaning because the offspring from SUP and CON dams were similar ($P = 0.64$) in weight (642.65 vs. 620.4 ± 17.86 pounds, respectively) after being transported back to the CGREC facility and managed under similar summer grazing conditions.

We reject our hypothesis that corn supplementation from mi- to late gestation increases colostrum

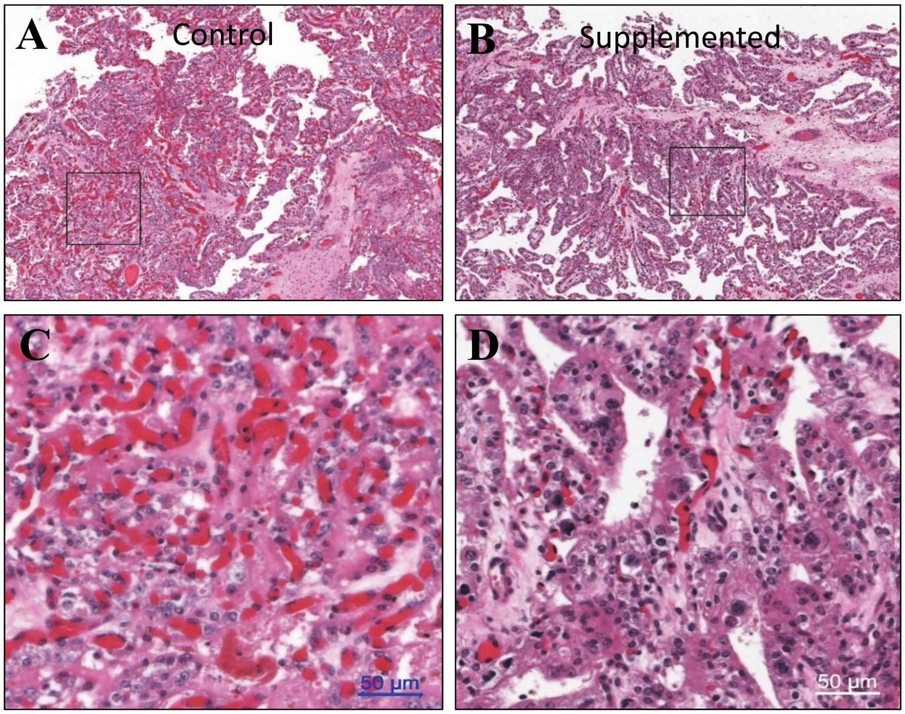

Figure 1. Hemotoxylin and eosin staining of cows fed the control (A) and supplemented (B) group from day 100 to day 240 of gestation. C and D are magnified sections of A and B (identified squares).

production and calf growth. This contrasts with a similar study by Radunz et al. (2012) in which beef cows limit-fed corn (63 percent of the diet) during late gestation produced calves that were heavier at birth than calves from dams fed hay.

Additionally, although most measurements of uterine blood flow and placental characteristics in the current study were unaltered by corn supplementation, placental vascularity was suppressed in the cotyledons from SUP dams. Perhaps this is because the fetuses from cows supplemented with corn already were receiving the necessary nutrients for normal fetal growth and did not need to produce as many factors that could alter or increase cotyledonary vasculature. Despite the potential reduction in nutrient exchange in the placentas from corn supplemented dams, what is important to note is that it did not impede normal fetal or calf growth.

While dietary energy intake in cows seems to alter vascularity of the fetal cotyledon, energy supplementation seems to have limited impacts on prenatal growth in the current study. Perhaps maintaining optimal protein-to-energy ratios would be the most effective for improving fetal growth. However, because corn supplementation does not affect neonatal growth up to weaning, corn appears to be a substitute for hay. We are examining the effects of maternal corn supplementation on offspring feed efficiency and carcass characteristics.

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Winter feeding strategies: Implications of corn supplementation on uterine and mammary blood flow

Amelia R. Tanner[1], Victoria C. Kennedy[1], Marc L. Bauer[1], Kendall C. Swanson[1], James D. Kirsch[1], Kimberly H. Ominski[2] and Kimberly A. Vonnahme[1]

Uterine blood flow plays a critical role in the development of the conceptus, allowing for the maternal-fetal exchange of nutrients, hormones and wastes. This study found that cows receiving corn supplement at 0.2 percent of body weight had unaltered uterine blood flow and calf birth weights, but mammary blood flow on the side opposite of the fetus decreased because of the corn supplement. Despite decreasing mammary blood flow, corn appears to remain a viable substitute for hay when forage cannot otherwise be provided (drought, winter, etc.).

Summary

The objective of this study was to evaluate the effects of supplementing gestating beef cows consuming low-quality forage with corn by tracking uterine and mammary blood flow dynamics. We hypothesized that mid to late gestating beef cows receiving corn supplementation would have greater uterine and mammary blood and give birth to heavier calves without increasing dystocia. Forty-seven multiparous Angus beef cows carrying bull calves were assigned randomly to treatments receiving corn supplementation at 0.2 percent of body weight (SUP; n = 24) or no supplement (CON; n = 23). All cows were fed the same basal diet of ad libitum access to low-quality forage. Intake was monitored individually with Insentec feeders from day 100 of gestation through calving. Blood flow to the uterus was monitored using Doppler ultrasonography every 28 days from the start of supplementation until day 240 of pregnancy. At birth, the calves were weighed. Corn supplementation reduced ($P < 0.001$) roughage intake by SUP cows; however, the Net Energy of Maintenance (NEm) consumed per day tended ($P = 0.06$) to increase in SUP cows. Supplemented cows gained more ($P \leq 0.03$) body weight and condition and had faster average daily gain (ADG; $P < 0.001$) than control cows. Uterine blood dynamics ($P > 0.20$) and calf birth weight ($P > 0.50$) were not altered by maternal corn supplementation. However, mammary blood flow contralateral to the conceptus was reduced ($P = 0.05$) in corn-supplemented cows. While corn did decrease roughage intake, it appears to be a good substitute for hay because it does not have negative effects on uterine blood flow or birth weights.

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Introduction

Doppler ultrasound is a noninvasive, repeatable way to measure changes in uterine blood dynamics to detect the consequences of poor maternal nutrition and target timing of therapeutic interventions (Vonnahme and Lemley, 2011). We previously demonstrated that the supplementation of dried distillers grains plus solubles (DDGS) to beef cows in late gestation increased dry-matter intake of a low-quality forage and increased uterine blood flow, thereby improving calf birth weights (Kennedy et al., 2016b). Thus, targeting winter nutritional management strategies during gestation is logical to increase uterine blood flow for improved fetal development and subsequent carcass characteristics.

We hypothesized corn supplementation to beef cows during mid to late gestation would result in greater total uterine blood flow and allow those dams to produce heavier calves without increased incidence of dystocia. The objectives of this study were to evaluate the effects of corn supplementation to gestating beef cows on uterine and mammary blood dynamics.

Experimental Procedures

The North Dakota State University Animal Care and Use Committee approved all procedures. Forty-seven multiparous beef cows (predominately Angus breeding) carrying bull calves (confirmed via ultrasonography at day 70 of gestation) from the Central Grasslands Research and Extension Center near Streeter, N.D., were transported to the Beef Cattle Research Complex in Fargo, N.D. The cows were assigned randomly to treatments (CON; n = 23) receiving ad libitum access to a low-quality forage-based diet only (57.54 percent total digestible nutrients [TDN = 96.35 – {%ADF x 1.15}], 6.4 percent crude protein [CP]) or (SUP; n = 24) an additional corn supplement at 0.2 percent of body weight.

Cows weighed 661 ± 7.8 kilograms (kg), had a body condition score of 5.2 ± 0.1 (9-point scale) and were 7.5 ± 0.2 years old at the start of the study. Intake was monitored and controlled via roughage intake control feeders beginning on day 100 of gestation for 22 weeks. At day 265 of pregnancy, all cattle were fed a common lactation diet (45 percent straw, 30 percent corn silage and 25 percent DDGS) that was higher in protein (11.6 percent CP) until three weeks postpartum.

Uterine blood flow changes were tracked every 28 days from day 100 to day 240 of pregnancy with Doppler ultrasonography measurements of the uterine artery. A finger probe was inserted into the rectum and the bifurcation of the external and internal iliac arteries were identified. Placement of the probe was immediately posterior to the first branch of the external iliac artery, measuring the descending uterine artery.

One observation was the average of three cardiac cycle waveform profiles from two to three ultrasound measurements that were collected from the uterine arteries ipsilateral (same horn) and contralateral (opposite horn) to the conceptus. Calving was monitored continuously from day 265 of gestation until all calves were born. The calves were weighed at birth.

All measurements and data collected were analyzed with generalized least squares procedure with repeated measures. Model statements included cow, maternal diet, day of gestation and a diet by day of gestation interaction. Sire was treated as a random variable.

Results and Discussion

Corn supplementation (3.24 ± 0.22 pound/day dry-matter [DM] basis) reduced ($P < 0.001$) roughage intake in SUP cows (28.22 vs. 31.75 ± 0.64 pound/day DM basis); however, TDN consumed tended to be greater ($P = 0.06$) in SUP cows because of the energetically dense corn that substituted for the decreased roughage intake in SUP cow diets.

Crude protein consumed was not different ($P = 0.81$) between dietary treatments (2.18 vs. 2.18 ± 0.44 pound/day). Additionally, a day by treatment interaction ($P < 0.05$) was observed for cow body weight and condition (Figure 1 as SUP cows gained more body weight and condition across gestation than nonsupplemented cows. Additionally, supplemented cows had greater

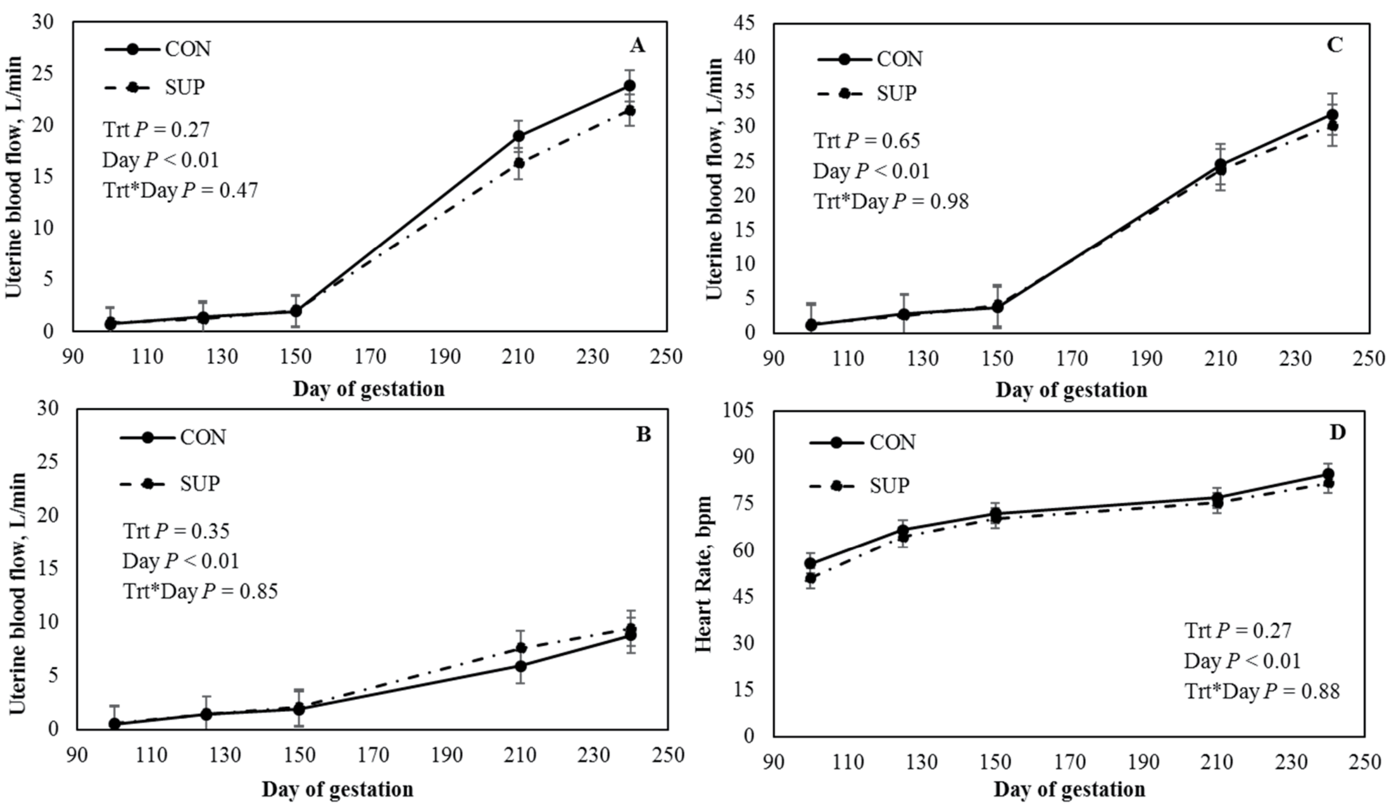

Figure 1. Pregnant side uterine arterial blood flow (A) and non-pregnant side uterine arterial blood flow (B) and total uterine arterial blood flow (C) and maternal heart rate (D) of beef cows fed the CON or SUP diets from day 100 to day 240 of gestation.

($P < 0.001$) ADG than CON cows (1.50 vs. 1.01 ± 0.18 pound/day).

Blood flow to the uterus (Figure 1), either total or to the horn on the same or opposite side of the fetus, was not affected ($P \geq 0.27$) by treatment or treatment interacting with day. As expected, uterine blood flow increased ($P < 0.01$) as gestation advanced in both treatment groups. Additionally, for maternal heart rate, no day by treatment interaction ($P = 0.88$) or maternal dietary treatment effect ($P = 0.27$) was detected over gestation, although heart rate increased over gestation ($P < 0.01$).

At day 240 of pregnancy, we found no effect ($P \geq 0.12$) of treatment on mammary blood flow ipsilateral (2.36 vs. 2.71 ± 0.27 liters per minute [L/min] SUP vs. CON) to the conceptus or total mammary blood flow (4.47 vs. 5.51 ± 0.47 L/min SUP vs. CON). However, mammary blood flow contralateral to the pregnant uterine horn was decreased ($P = 0.05$) in SUP vs. CON cows (2.11 vs. 2.80 ± 0.24 L/min). Calf birth weights (87.74 vs. 87.30 ± 2.20 pounds SUP vs. CON) also were unaffected ($P = 0.50$) by maternal corn supplementation with calves from SUP dams being similar to calves from CON cows at birth with no greater incidence of dystocia ($P = 0.50$).

We reject our hypothesis that corn supplementation from mid to late gestation would increase uterine blood flow to the gravid uterus and increase calf birth weight. While Net Energy of Maintenance (NEm) intake was increased in SUP cows, this did not alter uterine blood flow. This agrees with previous work by our lab, where cows were nutrient-restricted to 60 percent of their daily requirements during early (day 30 to 140) pregnancy and uterine blood flow was unchanged (Camacho et al., 2014).

To test the effects of components of the diet on uterine blood flow, beef cows were limit-fed forage while being fed a DDGS supplement in late gestation (day 190 to day 240; Mordhorst et al., 2016). This supplementation strategy resulted in a decrease in uterine blood flow without affecting calf birth weight (Mordhorst et al., 2016). However, when beef cows during late gestation (day 180 to 246) were supplemented with a DDGS protein supplement (0.3 percent of body weight) and could increase their forage consumption via ad libitum access to low-quality forage, uterine blood flows and calf birth weights were increased (Kennedy et al., 2016).

Perhaps metabolizable protein was driving these changes in uterine blood flow rather than total energy intake, as supported by the current study. However, if resources are limiting, corn supplementation appears to be a substitute for hay because it does not seem to reduce uterine blood flow or calf birth weights. Depending on the cost or availability of feed inputs, this may be an advantageous feeding strategy.

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The effects of day of estrus on dry-matter intake and feeding behavior in beef heifers

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The objectives of this study were to examine the relationship between estrus and the subsequent consequences on dry-matter intake (DMI) and feeding behavior in beef heifers of varying size. Heifers were categorized as small to moderate (SMD) or moderate to large (MLG) based on frame size, where MLG heifers had a greater DMI, spent more time eating, and had a greater number of meals and visits to feeders, compared with SMD heifers. All heifers experienced a significant drop in DMI, visits, time spent eating and number of meals consumed on the day of standing estrus.

Summary

Crossbred beef heifers (n = 73) originating from the NDSU Dickinson Research Extension Center (DREC) were shipped to the NDSU Beef Cattle Research Complex (BCRC) in Fargo, N.D., and acclimated to the Insentec feed system. Upon acclimation, heifers were assigned to pen by frame score, with treatments being small to moderate frame (SMD; frame score less than or equal to 5.50; n = 44) and moderate to large frame (MLG; frame score of 5.50 or greater; n = 29). On day one of the study, heifers were fitted with Accubreed heat detection devices to monitor behavioral estrous. Heifers were fed an ad libitum total mixed ration (TMR) diet for a duration of 107 days, during which time feed intake and behavior, as well as behavioral estrous activity data, were collected. Upon completion of the study, feed data from the Insentec system were combined with estrus data from Accubreed. We observed 266 estrus events, with a mean duration of 8.26 hours and 12.7 mounts lasting 4.06 seconds, for a total time standing of 49.1 seconds for a single cycle. We found an impact ($P < 0.001$) of frame size treatment on feed intake and behavior, with MLG heifers having a greater DMI and making more visits to troughs, spending more time eating and having a greater number of meals over all feeding events, compared with SMD heifers. On the other hand, SMD heifers spent more time per visit and meal, and consumed a higher DMI per visit per meal, compared with MLG heifers ($P < 0.001$). Heifers across all treatments experienced a decrease ($P < 0.001$) in DMI, visits to troughs, number of meals and time spent eating on day zero (standing heat) of the estrous cycle.

Introduction

The estrous cycle in beef cattle averages 21 days, with a period of standing estrus that occurs 30 to 35 hours pre-ovulation (White et. al., 2002). Producers who utilize embryo transfer or artificial insemination protocols must visually identify cattle in standing heat and breed them accordingly during this very short time frame. Estrous detection aids, such as electronic activity detecting devices, have proven to have an increased efficiency of accurately, detecting the onset of estrus by 37 percent when compared with visual detection alone (Stevenson et al., 1996).

As females near estrus, many behavioral changes occur, such as an increase in number of steps they take, with primiparous females displaying a higher number of steps, compared with multiparous females. In addition, a correlation occurs between an increased intensity of steps as more females are displaying behavioral estrus (Roelofs et al. 2005). Other behavioral changes that may occur include hyperactivity, vocalization, mounting behavior and general restlessness (Lovendahl et al., 2010).

Researchers have hypothesized that the behaviors associated with standing heat can have a negative effect on feed intake (Pahl et al., 2014; Reith et al., 2014). However, data regarding the impact of estrus on feeding behavior in the days before and after standing estrus are lacking. Our hypothesis for this study was that behavioral estrous activity would reduce DMI and alter feeding behavior, regardless of animal size.

Experimental Procedures

All procedures for this experiment were approved by the NDSU Animal Care and Use Committee. Seventy-three crossbred beef heifers originating from the NDSU Dickinson Research Extension Center were shipped to the NDSU Beef Cattle Research Complex in Fargo, N.D., and acclimated to the Insentec Feed

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system (Hokofarm Group B. V., the Netherlands) during an 18-day period. Treatments were determined based on frame score of the heifers: small to moderate (SMD; n = 44) or moderate to large (MLG; n = 29).

SMD heifers had an average start weight of 718 pounds and a frame score less than or equal to 5.50, whereas MLG heifers had an average start weight of 844 pounds and a frame score of 5.50 or greater. Frame score was calculated as a function of hip height and age per BIF (Beef Improvement Federation, 2016) guidelines.

Heifers received an ad libitum TMR consisting of 78.5 percent grass hay, 16.5 percent corn silage and 5 percent premix. The TMR was formulated to contain 11.79 percent crude protein on a DM basis for a targeted growth rate of 1.5 pounds per day and was provided for the 107-day experimental trial.

All heifers wore radio frequency identification tags to operate the Insentec system and to collect individual animal data, including daily dry-matter intake, number of visits to feeders per day and number of meals per day. A meal was defined as a distinct feeding event that consisted of breaks no longer than seven minutes. Calculations were made to determine time per visit, time per meal, and pounds DMI per individual visit and meal.

Each heifer received an Accubreed heat detection device on day one of the study. The Accubreed system consists of battery-powered radiotelemetry devices that are inserted into a mesh pouch and mounted to the tail head of each heifer. When the heifer was mounted, a button was depressed on the transmitter that sent a signal to the main station buffer, which then transmitted the data to a computer. Data recorded for each mounting event included animal ID, date and time, and duration of the mount.

A heifer was considered in standing heat (day zero) when she had received three mounts with a duration greater than or equal to two seconds within a four-hour period. Estrus behavior was monitored for 56 days prior to bull turnout in addition to the 45-day breeding period beginning Aug. 1, 2016 and concluding Sept. 15, 2016.

On completion of the experimental trial, data from the Insentec feed system were combined with Accubreed heat detection data. Feed intake and behavior were summarized by day for each individual heifer and aligned with day of estrus (day zero), as defined by the Accubreed system. All feed and behavioral estrous data were compiled for seven days prior (day minus seven) and seven days post estrus (day seven). Data were analyzed for the impact of treatment (SMD or MLG), day relative to estrus (days minus seven to seven), and their respective interaction using the general linear model procedures of SAS (SAS Institute Inc., Cary, N.C.).

Results and Discussion

Overall, 266 estrous cycles were observed with a mean duration of 8.26 hours (Table 1). The number of mounts per estrus ranged from two to 101 for a single cycle, with a duration ranging from two to 12.3 seconds. The time a heifer stood for mounting behavior ranged from six to 424 seconds within a single estrous cycle.

No interactions ($P \geq 0.64$) were present among treatment and day relative to estrus for any of the response variables measured. Therefore, impacts of the main effect of treatment and day relative to estrus are reported.

Dry-matter intake was influenced by treatment and day relative to estrus (Figure 1). Heifers in the MLG treatment consumed more ($P < 0.001$) on each day, compared with heifers in the SMD treatment, and both experienced a significant reduction ($P < 0.001$) in DMI on the day of estrus (day zero). Table 2 illustrates the impact of treatment (SMD vs. MLG) on feed intake and behavior.

SMD heifers spent less time eating, had fewer visits to troughs and ate fewer meals, compared with MLG heifers ($P < 0.001$). In contrast, SMD heifers also spent more time per visit and meal, and consumed a greater DMI per visit and meal, compared with MLG heifers ($P < 0.001$). The smaller physical size of the SMD heifers may have limited the rate at which they could consume feed, resulting in more time per visit and meal and more DMI per visit and meal, compared with the MLG heifers.

We observed a significant reduction in the time spent eating, visits to troughs and meals ($P < 0.001$) on the day of estrus (day zero), when compared with each of the seven days before and after (Table 3). These data highlight the short-term impact that behavioral estrous activity has on typical DMI and feeding behaviors across all treatments. These data support observations

Table 1. Summary of behavioral estrus activity from 266 recorded estrous events in crossbred heifers.

Item	Mean	Range
Mounts per estrus, no.	12.70	2 to 101
Mount duration, s	4.06	2 to 12.3
Time mounted, s	49.10	6 to 424
Estrus duration, h	8.26	<1 to 28.6

by Pahl et al. (2014) in which dairy cattle had reduced feed intake and feeding rate at estrus.

These results show that feed intake and behavior are altered by behavioral estrous activities. The observed alterations are rapid, and feed intake and behavior returned to baseline levels within one day following standing heat. These findings suggest that the onset of estrus and the subsequent reduction in DMI and alterations in feeding behavior may not have major performance impacts on individual heifers. However, the extent to which altered feeding behavior as a result of estrus in individual heifers plays a role in the social environment and feeding behavior of other heifers in a pen is yet to be determined.

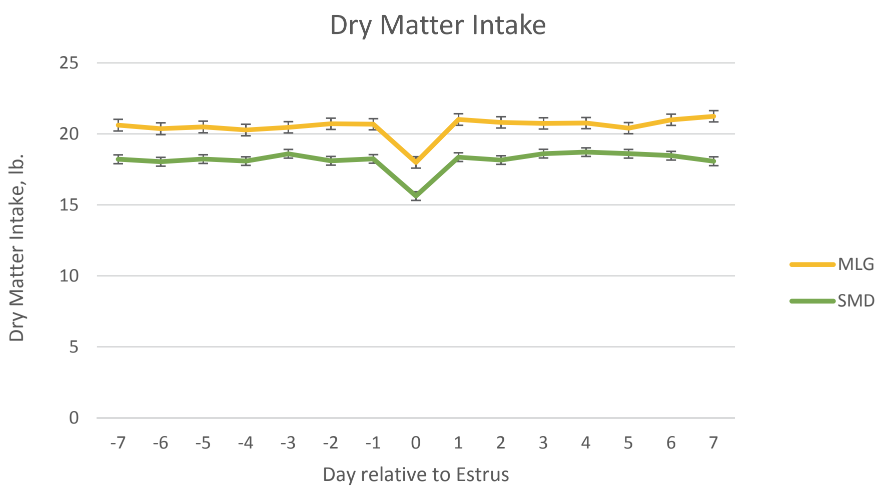

Figure 1. Impact of treatment and day relative to estrus on dry-matter intake for small to moderate (SMD) and moderate to large (MLG) crossbred heifers.

Table 2. Impact of treatment on feeding behavior in small to moderate (SMD) and moderate to large (MLG) crossbred heifers.

Item	SMD	MLG	SE	P-value
Dry-matter Intake, lb	18.14	20.58	0.088	< 0.001
Time eating, h	2.28	2.48	0.02	<0.001
Visits, no.	83.83	112.98	0.82	<0.001
Meals, no.	32.97	44.74	0.34	<0.001
Time per visit, s	102.46	87.68	1.32	<0.001
Time per meal, s	260.34	223.23	3.41	<0.001
DMI per visit, lb	0.231	0.194	0.002	<0.001
DMI per meal, lb	0.595	0.496	0.004	<0.001

Table 3. Impact of day on feeding behavior in crossbred heifers.

	Day Relative to Estrus																
Item	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	SE	*P*-value
Time eating, min	144.22	143.96	144.64	144.07	146.11	149.02	143.66	115.67	141.23	142.51	144.53	144.15	143.73	144.36	148.81	3.29	<0.001
Visits, no.	101.59	99.91	98.93	100.37	100.33	100.09	96.86	82.71	98.24	99.24	100.90	100.58	97.92	99.68	98.74	2.32	<0.001
Meals, no.	39.89	39.41	38.32	39.78	39.79	39.90	38.43	32.50	38.18	39.24	39.89	39.80	39.03	39.76	38.94	0.93	<0.001

Acknowledgments

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Whole or rolled corn in diets for backgrounding and finishing steers

Chanda L. Engel[1]

One hundred eighty-nine weaned cross-bred steer calves were used to evaluate feeding whole or rolled corn in growing and finishing feedlot diets. Through the growing and finishing phases of the trial, animal performance, feed efficiency and carcass traits were not different between cattle fed whole and rolled corn. This research indicates that in diets with 15 percent or higher forage levels, whole corn can be fed in the backgrounding and finishing phases without loss to performance and feed efficiency.

Summary

One hundred eighty-nine weaned cross-bred steer calves were blocked by body weight to evaluate feeding whole or rolled corn in diets for the growing and finishing feedlot phases. Corn levels in the diets were similar between whole and rolled-corn treatment diets. Diets were similar in crude protein and energy between whole and rolled-corn diets. The growing phase was 61 days and the finishing phase was 79 days, for a total of 140 days on feed. Hot carcass weights were recorded on the day of harvest. Carcass 12th rib-fat thickness, longissimus muscle area and U.S. Department of Agriculture (USDA) marbling score and yield grades (YG) were recorded following a 24-hour chill. Animal performance and carcass data were analyzed using the GLM procedures of SAS for a randomized complete block design, with pen as the experimental unit. Least square means were separated using the PDIFF statement of SAS. The average starting weight was 666 pounds. Average daily gain and dry-matter intake were not different between whole and rolled-corn diets in the growing and finishing periods. Thus, for the growing and finishing periods, the feed-to-gain ratio was similar for whole and rolled-corn fed cattle. Carcass characteristics were not different between whole and rolled-corn fed cattle. Results suggest that in diets with greater than 15 percent forage, corn grain can be fed whole in the backgrounding and finishing phases without loss to performance and feed efficiency.

Introduction

Typically, when corn is included in cattle rations, particularly in backgrounding and finishing diets, it is processed by dry rolling, grinding or steam flaking. In North Dakota, the processing method is typically dry rolling or grinding.

However, not everyone has the ability to process corn on the farm and it is an added cost. Additionally, the body of research that has evaluated corn processing method and levels of processing has yielded mixed results.

In some cases, researchers found no difference between animal performance or feed efficiency when corn is rolled or fed whole. In other instances, animal performance may be similar, but dry-matter intake is increased when whole corn is fed, and thus feed efficiency is improved with processing vs. whole corn. Age and the production phase may be factors.

During the past three years, the North Dakota State University Carrington Research Extension Center (CREC) has conducted feedlot research evaluating when and if rolling is beneficial or when feeding corn whole is comparable to rolled-corn diets. The first two research trials at the CREC were yearling steer feedlot finishing trials with higher than typical forage levels. The current trial evaluated feeding whole or rolled corn in a traditional backgrounding and finishing diet.

Experimental Procedures

The NDSU Animal Care and Use Committee approved all procedures. One hundred eighty-nine weaned cross-bred steer calves (666 pounds initial body weight) were blocked by body weight and sorted into four weight blocks. Within block, cattle were assigned randomly and sorted into one of 16 pens.

Pens were assigned randomly to one of two dietary treatments to evaluate feeding whole or rolled corn in diets for the growing and finishing feedlot phases. Corn levels in the diets were similar between whole and rolled-corn treatment diets (Table 1): 25 and 50 percent of the diet dry matter for growing and finishing periods, respectively. The dietary forage levels also were similar for whole and rolled-corn

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diets and were 30 and 15 percent for the growing and finishing periods, respectively.

Diets were similar in crude protein and energy between whole and rolled-corn diets. The growing phase was 61 days and the finishing phase was 79 days, for a total of 140 days on feed. Throughout the feeding trial, cattle were weighed approximately every 28 days.

All steers were marketed on the same day at a commercial abattoir (Tyson Foods, Dakota City, Neb.). Hot carcass weights were recorded on the day of harvest. Carcass 12th rib-fat thickness (BF), longissimus muscle area (LMA), and USDA marbling score and yield grades (YG) were recorded following a 24-hour chill.

Animal performance and carcass data were analyzed using the GLM procedure of SAS for a randomized complete block design, with pen as the experimental unit.

Results and Discussion

The average starting weight was 666 pounds (Table 2). In the growing period, cattle gained 3.22 pounds/head/day on the rolled and whole-corn diets. Dry-matter intake was not different between whole and rolled-corn diets, at 18.9 pounds/head/day (Table 3).

The steers weighed 863 pounds at the end of the growing period and finished at 1,399 pounds (Table 2). In the finishing period, gains were not different between whole and rolled-corn diets, at 3.9 pounds/head/day. Dry-matter intakes also were not different, at 24 pounds/head/day. Thus, for the growing and finishing periods, the feed-to-gain ratio was similar for whole and rolled-corn fed cattle.

Table 1. Growing and finishing diets and diet nutrient composition for steers fed whole or rolled corn.

	Growing		Finishing	
	Rolled corn	Whole corn	Rolled corn	Whole corn
Item	Dry matter, percent			
Corn	25.5	25.5	50.9	51.1
MDGS[1]	27.6	27.5	25.9	25.9
Corn silage	26.2	26.2	12.1	12.1
Straw	18.1	18.0	8.7	8.6
Supplement[2]	2.7	2.7	2.4	2.3
Nutrient composition	Dry-matter basis			
Diet dry matter, %	60.7	60.7	68.2	68.2
Crude protein, %	13.4	13.2	13.7	13.3
NDF, %[3]	34.0	33.8	22.2	21.9
TDN, %[4]	51.7	51.7	59.9	60.1
NEm, Mcal/lb[5]	0.78	0.78	0.87	0.87
NEg, Mcal/lb[6]	0.50	0.50	0.58	0.59

[1]Modified distillers grains.
[2]Vitamin and mineral supplement including an ionophore.
[3]Neutral detergent fiber.
[4]Total digestible nutrients.
[5]Net energy for maintenance.
[6]Net energy for gain.

Table 2. Performance for steers fed growing and finishing diets with whole or rolled corn.

Treatment	Rolled Corn	Whole Corn	Standard Error	*P*-value
Initial weight day 0, lb.	667	666	1.2	0.65
Weight day 61, lb.	862	863	5.01	0.93
Final weight day 140, lb.	1,396	1,403	12.2	0.69
Growing ADG[1]	3.22	3.23	0.09	1.00
Finishing ADG[2]	3.91	3.96	0.06	0.56
Overall ADG[3]	3.70	3.72	0.07	0.80

[1]Average daily gain day 0 to day 61.
[2]Average daily gain day 61 to day 140.
[3]Average daily gain day 0 to day 140.

Carcass characteristics were not different between whole and rolled-corn fed cattle (Table 4). Hot carcass weights were 843 pounds, with 0.48 inch of back fat. Quality grade was low choice, yield grade was 2.5 and rib-eye area was 13.4 square inches.

The animal performance results were consistent with what we have observed in our previous two trials with whole and rolled corn in high-forage diets (Engel et al., 2014 and 2015). We also observed similar dry-matter intakes (DMI) between whole and rolled-corn diets in one of the yearling trials when hay was the forage source.

However, when corn silage was included as the forage source, DMI was greater for the whole-corn fed cattle. In the high-forage trials with yearling cattle, the gain-to-feed ratio

Table 3. Feed intake and feed efficiency for steers fed growing and finishing diets with whole or rolled corn.

Treatment	Rolled Corn	Whole Corn	Standard Error	*P*-value
Growing dry-matter intake, lb./head/day[1]	18.9	18.9	0.14	0.85
Finishing dry matter intake, lb./head/day[2]	23.9	24.8	0.45	0.21
Overall dry-matter intake, lb./head/day[3]	22.3	23.0	0.31	0.21
Growing gain:feed[1]	0.172	0.172	0.005	0.98
Finishing gain:feed[2]	0.164	0.160	0.002	0.23
Overall gain:feed[3]	0.166	0.163	0.002	0.26

[1]Growing period day 0 to day 61.
[2]Finishing period day 61 to day 140.
[3]Day 0 to day 140.

Table 4. Carcass performance for steers fed growing and finishing diets with whole or rolled corn.

Treatment	Rolled Corn	Whole Corn	Standard Error	*P*-value
Hot carcass weight, lb.	842.0	844.9	8.5	0.82
Yield grade[1]	2.5	2.5	0.10	1.00
Rib-eye area, sq. In.	13.4	13.4	0.13	1.00
Marbling score[2]	455	451	8.29	0.71
Back fat, in.	0.48	0.48	0.01	1.00

[1]Yield grade is a composite calculation of fat to lean yield in a carcass based on a relationship of hot carcass weight, rib-eye area, fat thickness and KPH; Low values = lean carcasses.
[2]USDA Quality grades based on marbling scores of 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700+ = prime.

tended to be higher for rolled-corn diets. However, in the current study, the gain-to-feed ratio was similar with whole and rolled-corn diets for the growing and finishing phases.

This research suggests that in diets with greater than 15 percent forage, corn grain can be fed whole in the backgrounding and finishing phases without loss to performance and feed efficiency.

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Discovering value in North Dakota calves: Dakota Feeder Calf Show feedout project XV, 2016-2017

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The Dakota Feeder Calf Show feedout project assists cattle producers in identifying cattle with superior growth and carcass characteristics. The spread in average profitability between consignments from the top five herds and the bottom five herds was $224.84 per head for the 2016-2017 feeding period.

Summary

The Dakota Feeder Calf Show feedout project was developed to discover the actual value of spring-born beef steer calves, provide comparisons among herds, and benchmark feeding and carcass performance. Cattle consigned to the feedout project were delivered to the Carrington Research Extension Center Livestock Unit on Oct. 15, 2016. After a 213-day feeding period with 2.93 percent death loss, cattle averaged 1,334.9 pounds (shrunk harvest weight). Feed required per pound of gain was 6.77 (dry-matter basis). Overall pen average daily gain was 3.14 pounds. Feed cost per pound of gain was $0.494 and total cost per pound of gain was $0.743. Profit ranged from $790.79 per head for pen-of-three cattle with superior growth and carcass traits to $456.82 per head (no death loss). Substantial variability in the feeding and carcass value of spring-born calves continues to be discovered through participation in the feedout project.

Introduction

Determining calf value is a learning experience for cow-calf producers. To remain competitive with other livestock and poultry in the meat industry, cow-calf producers need to identify superior genetics and management. Marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

In addition, cost-effective feeding performance is needed to justify the expense of feeding cattle past weaning. Because North Dakota has low-cost feeds and a favorable climate, low cost per pound of gain can be accomplished (Hoppe et al., 1997).

Combining the low cost of gains with the identification of superior cattle, this ongoing feedlot project provides cattle producers with an understanding of cattle feeding and cattle selection in North Dakota.

Experimental Procedures

The Dakota Feeder Calf Show was developed for cattle producers willing to consign steer calves to a show and feedout project. The calves were received in groups of three or four on Oct.15, 2016, at the Turtle Lake Weighing Station, Turtle Lake, N.D., for weighing, tagging, veterinary processing and showing. The calves were evaluated for conformation and uniformity, with the judges providing a discussion to the owners at the beginning of the feedout. The number of cattle consigned was 205, of which 179 competed in the pen-of-three contest.

The calves then were shipped to the Carrington Research Extension Center, Carrington, N.D., for feeding. Prior to shipment, calves were vaccinated, implanted, dewormed and injected with a prophylactic long-acting antibiotic. Cattle were implanted with Synovex S upon arrival.

Calves then were sorted and placed on corn-based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.62 megacalorie of net energy for gain (Mcal NEg) per pound finishing diet. Cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were reimplanted with Revlor S.

An open house was held on Feb. 7, 2016, at the Carrington Research Extension Center Livestock Unit, where the owners reviewed the calves and discussed marketing conditions.

The cattle were harvested on May 17, 2017 (199 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Neb., on a grid basis, with premiums and discounts based on carcass quality. Carcass data were collected after harvest.

Ranking in the pen-of-three competition was based on the best overall score. The overall score was determined by adding the index values for feedlot average daily gain (25 percent of score), marbling score (25 percent of score) and profit (25 percent of score) and subtracting index value for calculated yield grade (25 percent of score). The Dakota Feeder Calf Show provided awards and recognition for the top-ranking pen of steers.

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Table 1. Feeding performance — 2016-2017 Dakota Feeder Calf Show Feedout

Pen of Three	Best Three Score Total	Average Birth Date	Average Weight per Day of Age, lbs.	Average Harvest Weight, lbs.	Average Daily Gain, lbs.	Average Marbling Score[1]	Average Calculated Yield Grade	Average Feeding Profit or Loss/Head
1	1.834	30-Mar-16	3.605	1558.3	4.037	546.3	3.538	$747.56
2	1.794	9-Mar-16	3.156	1433.3	3.364	482.7	2.643	$745.63
3	1.782	24-Mar-16	3.277	1435.0	3.426	494.3	2.762	$732.49
4	1.758	21-Feb-16	3.160	1493.3	3.522	571.7	3.752	$790.79
5	1.752	8-Apr-16	3.529	1493.3	3.717	459.0	2.670	$681.63
Average Top 5 herds	**1.784**	**19-Mar-16**	**3.345**	**1482.667**	**3.613**	**510.800**	**3.073**	**$739.62**
6	1.750	17-Apr-16	3.533	1460.0	3.724	434.3	2.471	$671.68
7	1.749	12-Apr-16	3.327	1391.7	3.490	520.3	2.909	$687.42
8	1.738	18-Apr-16	3.456	1423.3	3.686	544.7	3.504	$729.39
9	1.715	2-Mar-16	3.328	1536.7	3.645	425.3	3.026	$782.68
10	1.679	30-Mar-16	3.355	1451.7	3.391	503.0	3.256	$741.30
11	1.666	3-Apr-16	2.934	1255.0	3.201	542.7	2.763	$612.72
12	1.660	5-Mar-16	3.263	1496.7	3.342	479.3	2.948	$703.99
13	1.640	5-Apr-16	3.086	1313.3	3.438	422.3	2.466	$649.04
14	1.637	11-Apr-16	3.680	1543.3	3.636	585.7	4.102	$720.77
15	1.634	18-Apr-16	3.476	1431.7	3.793	459.7	3.048	$644.67
16	1.624	9-Apr-16	3.212	1355.0	3.397	501.7	2.775	$598.76
17	1.600	19-Mar-16	3.230	1433.3	3.170	441.0	2.816	$711.66
18	1.592	24-Mar-16	3.261	1430.0	3.170	509.3	3.122	$675.30
19	1.589	22-Mar-16	3.361	1481.7	3.431	485.3	3.290	$689.95
20	1.586	18-Mar-16	3.260	1453.3	3.399	543.7	3.192	$594.94
21	1.583	20-Apr-16	3.465	1420.0	3.858	449.0	3.306	$657.15
22	1.559	28-Mar-16	3.248	1411.7	3.237	516.7	3.336	$668.16
23	1.541	25-Mar-16	3.189	1391.7	3.000	490.3	2.871	$639.59
24	1.532	16-Apr-16	3.411	1415.0	3.727	443.0	3.087	$602.86
25	1.521	13-Apr-16	3.357	1401.7	3.340	469.0	3.014	$616.63
26	1.505	19-Apr-16	3.408	1401.7	3.558	444.0	3.337	$661.78
27	1.501	25-Feb-16	3.111	1455.0	3.219	542.3	3.751	$673.08
28	1.484	3-Apr-16	3.006	1286.7	3.358	385.0	2.323	$555.32
29	1.441	16-Mar-16	2.944	1315.0	2.978	394.0	2.121	$537.71
30	1.421	20-Apr-16	3.119	1278.3	3.204	441.0	2.868	$566.81
31	1.413	28-Apr-16	3.546	1423.3	3.514	370.7	2.641	$550.74
32	1.399	12-Apr-16	3.444	1443.3	3.588	410.0	3.302	$606.40
33	1.391	12-Mar-16	3.171	1431.7	3.287	419.3	2.540	$488.83
34	1.384	10-Mar-16	2.909	1316.7	2.791	407.7	2.116	$506.20
35	1.384	24-Apr-16	3.331	1351.7	3.336	359.3	2.383	$523.26
36	1.355	23-Mar-16	3.340	1468.3	3.068	401.3	3.288	$676.64
37	1.348	15-Apr-16	3.469	1438.3	3.285	458.3	3.769	$650.69
38	1.339	19-Mar-16	2.920	1295.0	3.045	421.3	2.793	$539.61
39	1.316	21-Mar-16	3.151	1391.7	3.101	427.7	3.362	$617.31
40	1.313	30-Mar-16	3.197	1381.7	3.181	369.7	2.505	$503.80
41	1.277	2-May-16	2.881	1146.7	2.704	407.3	2.229	$456.82
42	1.178	12-Apr-16	3.084	1293.3	2.983	395.3	3.077	$510.28
43	1.171	28-Apr-16	3.374	1355.0	3.343	409.0	3.406	$485.66
Average bottom 5 herds	**1.251**	**12-Apr-16**	**3.137**	**1313.7**	**3.062**	**401.8**	**2.916**	**$514.77**
Overall average - pens of three	**1.538**	**1-Apr-16**	**3.269**	**1404.3**	**3.365**	**460.1**	**2.988**	**632.74**
Standard deviation		17.7	0.2	83.0	0.3	58.4	0.5	86.6
number	43	43	43	43	43	43	43	

[1]Marbling score 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700-799 = low prime

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 623.8 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on Oct. 15, 2016. After an average 213-day feeding period, cattle averaged 1,334.9 pounds (at plant, shrunk weight). Death loss was 2.93 percent (six head) during the feeding period.

Average daily feed intake per head was 32.4 pounds on an as-fed basis and 21.4 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 10.25 on an as-fed basis and 6.77 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.494. The overall yardage cost per pound of gain was $0.100. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.743.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.035172919* initial calf weight, pounds) + 145.5825919) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

Overall, the carcasses contained U.S. Department of Agriculture Quality Grades at 3.5 percent Prime, 73.4 percent Choice or better (including 11.5 percent Certified Angus Beef), 22.1 percent Select, 0.5 percent Standard and 0.5 percent other, and USDA Yield Grades at 9 percent YG1, 45.2 percent YG2, 40.2 percent YG3, 5 percent YG4 and 0.50 percent YG5. One carcass (0.50 percent) was greater than 1,050 pounds.

Carcass value per 100 pounds (cwt) was calculated using the actual base carcass price plus premiums and discounts for each carcass. The grid price received for May 17, 2017, was $224.84 Choice YG3 base with premiums: Prime $20, CAB $6, YG1 $6.50 and YG2 $2, and discounts: Select minus $15, Standard (no roll) minus $15, YG4 minus $8, YG5 minus $20 and carcasses greater than 1,050 pounds minus $20.

Results from the calves selected for the pen-of-three competition are listed in Table 1.

Overall, the pen-of-three calves averaged 410 days of age and 1,403.9 pounds per head at harvest. The overall pen-of-three feedlot average daily gain was 3.36 pounds, while weight gain per day of age was 3.27 pounds. The overall pen-of-three marbling score was 461.2 (low choice, small marbling).

Correlations between profit and average birth date, harvest weight, average daily gain, weight per day of age or marbling score are shown in Table 2. The average harvest weight, average daily gain and marbling score had positive correlations to profitability.

The top-profit pen-of-three calves with superior genetics returned $790.79 per head, while the bottom pen-of-three calves returned $456.82 per head. The average of the five top-scoring pens of steers averaged $739.62 per head, while the average of the bottom five scoring pens of steers averaged $514.77 per head.

For the pen-of-three competition, average profit was $632.83 per head. The spread in profitability between the top and bottom five herds was $224.84 per head.

Implications

Calf value is improved with superior carcass and feedlot performance. Exceptional average daily gains, weight per day of age, harvest weight and marbling score can be found in North Dakota beef herds. Feedout projects provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

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Table 2. Correlation between profit and various production measures (pen-of-three).

Correlation coefficient	Correlation coefficient
Profit and average birth date	-0.3783
Profit and average harvest weight	0.7301
Profit and average daily gain	0.5205
Profit and weight per day of age	0.4457
Profit and marbling score	0.6329
Profit and yield grade	0.5088

Effect of a low vitamin A diet on marbling and carcass characteristics of Angus cross and Simmental steers

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The objective of this experiment was to determine the effect on carcass and production characteristics of removing vitamin A supplementation from growing and finishing diets of commercial Angus and purebred Simmental steers. Removal of vitamin A supplementation increased marbling in commercial Angus cattle but had no effect in Simmental cattle. Removal of vitamin A supplementation also increased average daily gain in both breeds.

Summary

Commercial Angus steers consisting of a minimum of 75 percent Angus genetics (Angus x Simmental) and purebred Simmental steers were used to evaluate the effect of a low vitamin A (VA) diet on growth and meat quality characteristics. After three months of backgrounding on a low vitamin A diet (1,017 International Units per kilogram [IU/kg]), 64 steers (32 Angus cross, 32 Simmental) were allocated to one of two dietary treatments for finishing. The basal diet was low in VA (723 IU/kg). One treatment consisted of the basal diet with no supplemental VA (LVA); the other (CON) was supplemented with VA at the National Research Council's recommended level of 2,200 IU/kg dry matter (DM). At the completion of finishing, steers were slaughtered at a commercial abattoir. Two strip loin steaks were collected from each steer to analyze meat quality characteristics, including ether extract, color (L*, a*, b*), Warner-Bratzler sheer force, cook loss, subjective marbling score (scored by trained personnel), and pH. Camera image analysis from the slaughter plant was used for analysis of marbling, 12th subcutaneous (s.c.) fat, longissimus muscle area, hot carcass weight, kidney-pelvic-heart fat, and quality and yield grades. We found a difference ($P < 0.01$) in marbling score between the LVA Angus cross group and all other groups. The LVA treatment resulted in a 16 percent increase in marbling among treatments within the Angus cross group, but it had no effect in Simmental cattle. Within the Angus cross cattle, the LVA treatment resulted in 26.6 percent of cattle grading higher (choice improving to prime) than their CON counterparts.

Introduction

Marbling is one of the most influential factors that affect consumer preference in meat; generally, palatability increases with increased marbling through factors such as tenderness, juiciness and taste (Smith, 2014; Wang et al., 2009). Marbling also is known as interfascicular or intramuscular adipose tissue and is different than other types of fat because it is deposited alongside muscle fibers.

Intramuscular fat deposition is more complex than that of subcutaneous fat in beef cattle; it is affected by the genetic propensity to marble, nutritional plane throughout life and environmental factors. Vitamin A (VA) restriction has been shown to enhance marbling in cattle that genetically have a high propensity to marble, such as Angus and Tijama cattle, but not in cattle with a low propensity to marble, such as Limosin cross cattle (Oka et al., 1998; Wang et al., 2007).

The effect of VA on fat development varies throughout the differing stages of development. Retinoic acid (a VA derivative) affects fat development by regulating the expression of adipogenic genes. Prior studies have shown inconsistent results on the effects of vitamin A restriction on production traits such as average daily gain, dry matter intake and gain-to-feed ratio; the majority of work shows no negative effects unless cattle reach deficiency status.

Restricting dietary vitamin A may be a strategy to increase marbling without negatively impacting other production characteristics. The effect of VA restriction on cattle with high or low propensity to marble has yet to be compared, and this may be an important aspect to consider when determining VA supplementation. The hypothesis of this study is that a low VA diet would increase marbling and improve meat quality characteristics while having no effect on production characteristics of Angus cross and Simmental steers.

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Experimental Procedures

All procedures involving animals were approved by the NDSU Animal Care and Use Committee. Simmental and Angus cross steers (n = 32 per breed) were obtained from the North Dakota State University Beef Unit. Previously, these steers had been grazing on summer pasture, therefore likely had high liver VA stores.

The steers were fed a growing diet containing low concentrations (1,017 IU/kg DM) of VA for three months (Table 1). This diet was designed to begin to deplete the liver VA stores, which can sustain serum retinol for two to four months (NRC, 1996). Steers then were moved to the North Dakota State University Beef Cattle Research Complex, where they were allocated to treatment.

A total of 16 steers per breed were allocated to each nutritional treatment. The LVA treatment was the basal diet that contained 723 IU/kg of DM (Table 1). The CON treatment was the basal diet plus a supplement containing the NRC (2016)-recommended 2,200 IU of VA/kg of DM.

Steers were slaughtered in two groups after 150 and 180 days of finishing, when they reached approximately 1,300 pounds of body weight (BW). Steers were slaughtered at the Tyson slaughter facility (Tyson Fresh Meats, Dakota City, Neb.), where camera carcass data were collected by trained Tyson personnel. This data included kill date, grade date and time, lot number, carcass ID, hot carcass weight (HCW), sex, USDA Quality Grade (QG), USDA Yield Grade (YG), calculated yield grade (CYG), longissimus muscle area (LMA), marbling score, back fat depth and kidney pelvic heart fat (KPH) percentage.

A boneless strip loin was collected from each carcass. The loins were transported back to the NDSU Meats Lab, where they were aged for two weeks. After aging, two 1-inch steaks were cut from the center section of each loin. Steaks were analyzed for meat quality characteristics, including subjective marbling score, marbling texture score, ether extract, Minolta color score, pH, drip loss and Warner-Bratzler shear force.

Subjective marbling and marbling texture scores were assigned by an experienced grader. Ether extract was performed by the NDSU Nutrition Lab. The Minolta color score was scored with a Chroma Meter CR-410 (Konica Minolta, Tokyo, Japan). Meat pH was measured with a meat pH meter (Hanna HI99163, Hanna Instruments, Woonsocket, R.I.)

Steak weights were recorded and the steaks were cooked to a final temperature of 71 C with a clamshell-style grill (George Forman Lean Mean Fat-reducing Grilling Machine, Spectrum Brands Inc., Madison, Wis.), and cooked weights were recorded to calculate cook loss. After cooking, steaks were placed on a metal tray to allow to cool to room temperature.

After cooling to room temperature, six 1.27centimeter cores were removed from each steak parallel to the muscle fiber orientation. These cores were sheared perpendicular to the muscle fibers using a Mecmesin BFG500N force gauge. (Mecmesin, Slinfold, West Sussex, U.K.)

Data were analyzed using the mixed procedure of SAS (v. 9.4; SAS Inst., Cary, N.C.). Data were modelled in a 2x2 factorial treatment arrangement, with breed, treatment and their interaction as fixed effects of interest; slaughter date was used as a fixed effect to remove variation. Steer served as the experimental unit. Means were separated using the LSMEANS procedure, and *P*-values ≤ 0.05 were considered significant.

Table 1. Ingredient and nutrient composition (DM basis) of total mixed ration growing and finishing diets.

Item	Growing, %	Finishing, %
Ingredient		
Brome hay	15.0	–
Wheat straw	30.0	10.0
Barley	10.0	–
Corn	20.0	60.0
CSB[2]	–	5.0
DDGS[3]	20.0	20.0
Supplement[1]	5.0	5.0
Nutrient composition		
CP	15.0	14.7
NDF	48.2	25.5
ADF	26.0	10.3
Ca	0.69	1.01
P	0.32	0.53

[1]Supplement contained ground corn, limestone, urea, salt, monensin (176.4 grams per kilogram [g/kg] premix, Elanco, Greenfield, Ind.), tylosin (88.2 g/kg premix, Elanco), vitamin D (3,000 IU/kg) and a trace mineral premix.

[2]Concentrated separator byproduct (partially de-sugared beet molasses).

[3]Dried distillers grains with solubles.

Results and Discussion

Production Characteristics

The average daily gain (ADG) of steers in the LVA treatment was greater ($P = 0.03$) than for those in the CON treatment; however, we found no effect of treatment ($P = 0.44$) on final body weight. Increased ADG is likely a result of the numerically greater dry-matter intake (0.2 pound/day) seen in the LVA treatment. This is in contrast with most other studies that have shown no difference in ADG with vitamin A restriction. We found no effect of VA treatment on any other production measurement.

Final body weight was greater ($P < 0.001$) for the Angus cross than Simmental steers (1,371 ± 25 and 1,284 ± 27 pounds, respectively). This is likely a result of the numerically greater dry-matter intake seen by Angus-cross steers than Simmental steers (25.1 and 22.6 pounds, respectively). Simmental steers were more efficient, having a greater ($P = 0.02$) gain-to-feed ratio than the Angus steers (0.1416 and 0.1338, respectively). Interestingly, we found no effect of breed or treatment on hot carcass weight ($P = 0.28$), as there was with final BW.

Meat Quality Characteristics

We observed an interaction of breed and treatment on marbling score ($P = 0.008$); (Figure 1). Within the Angus-cross steers, the LVA treatment had 16 percent greater marbling scores than CON Angus steers. We found no difference in marbling score between LVA and CON in Simmental steers. This is consistent with prior research showing that vitamin A restriction increases marbling in cattle with high propensity to marble, but not

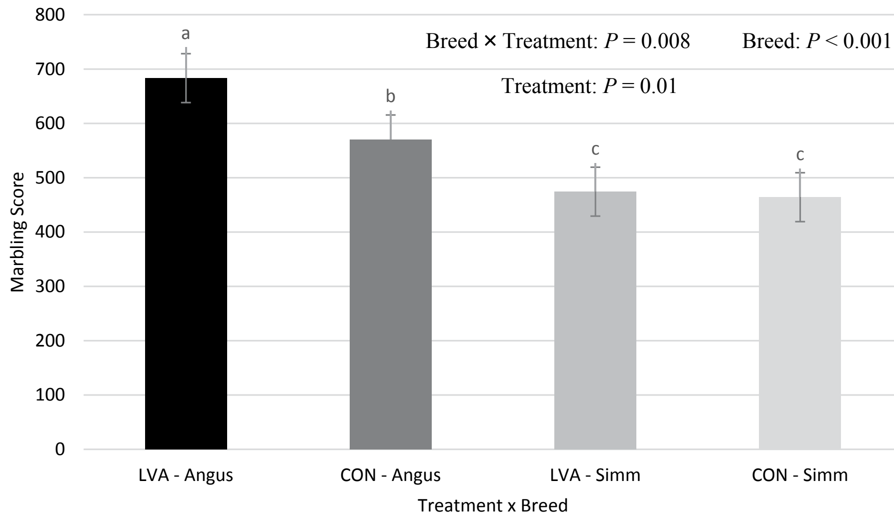

Figure 1. Marbling score of the *longissimus* of commercial Angus (Angus) or purebred Simmental (Simm) steers fed a finishing diet with low vitamin A (LVA) or control (CON; supplemented with 2,200 IU vitamin A/kg DM). Marbling score was assessed using computer image analysis.

[abc]Means not sharing a common superscript are different ($P < 0.05$).

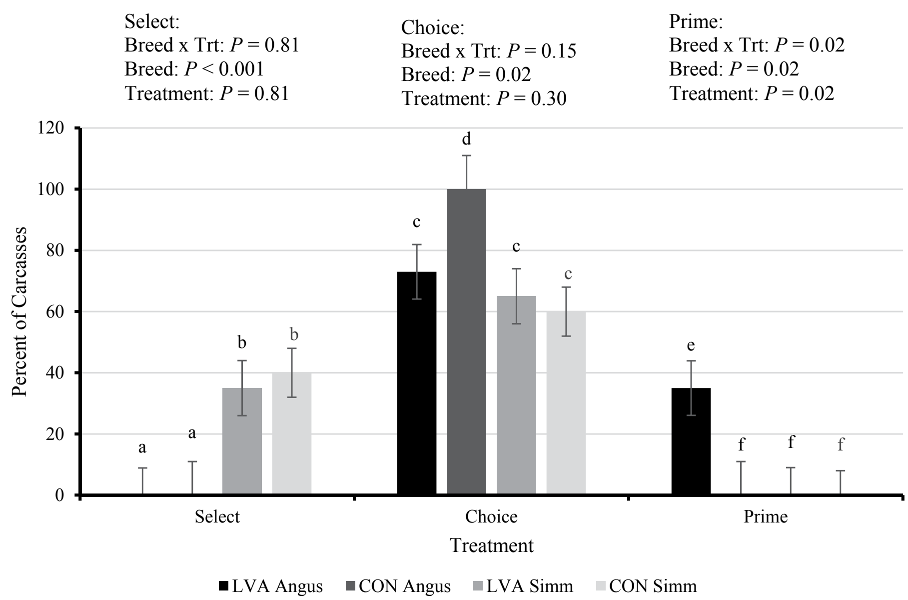

Figure 2. Quality grades of finishing cattle compared across treatment (Trt) and breed. Dietary treatments consisted of low vitamin A (LVA), which contained no supplemental vitamin A, and control (CON), which contained supplemental 2,200 IU vitamin A/kg DM. The breeds were commercial Angus (Angus; minimum 75 percent Angus genetics) and pure bred Simmental (Simm).

[abc]Means not sharing a common superscript within each quality grade are different ($P < 0.05$).

in cattle with low propensity to marble.

The difference in marbling score resulted in quality grade differences. A greater proportion ($P = 0.02$) of Angus cross cattle graded choice than Simmental steers (Figure 2). The LVA Angus cross treatment was the only treatment to produce prime carcasses, resulting in 33 percent prime carcasses.

Ether extract analysis was highly correlated with marbling score, with observed main effects of treatment and breed ($P = 0.04$ and $P < 0.001$, respectively) but no interaction. Angus cross steers had greater ($P < 0.001$) back fat and KPH fat than Simmental steers. Conversely, Simmentals had a longissimus muscle area (LMA) ($P < 0.001$). Subsequently, the Angus cross exhibited greater Yield Grade ($P < 0.001$), having a lower percentage of closely trimmed retail cuts.

Cook loss was higher in the LVA treatment than the CON treatment (20.4 and 17.5 percent, respectively; $P = 0.04$). Interestingly, we found a difference in meat pH between the Angus cross group and Simmental group ($P < 0.001$). Finally, we observed a tendency for steaks from Simmental steers to be more red (a* value) than steaks from their Angus cross counterparts ($P = 0.05$).

Increasing marbling has the potential to add significant value to a beef carcass. According to the results of this research, feeding a low VA diet to cattle that have a genetic high propensity for marbling would function to increase the profits of cattle producers and packers without increasing the cost of production. The increase in marbling without increasing other fat depots increases quality grade without a negative impact on yield grade.

In cattle that have a lower propensity to marble, VA restriction appears to have no effect on marbling, but it increased ADG. No adverse effects on production characteristics or carcass characteristics were apparent when VA was not supplemented in the diet of either breed of cattle. Therefore, reducing or removing vitamin A supplementation from cattle finishing diets may be beneficial, although producers need to take care to avoid VA deficiency.

Steer performance, carcass measurements and value of rotation crop, cover crop and bale grazing in western North Dakota

Songül Şentürklü[1,2], Douglas Landblom[1] and Steve Paisley[3]

Yearling steers that grazed native range (NR) or annual forages (ANN) were compared in a retained-ownership birth-to-slaughter study. Grazing cover-crop bales extended the grazing season from 180 to 221 days. Steers grazing annual forage sequence crops and cover-crop bales maintained seasonal average daily gain (ADG) above 2 pounds per day, had a greater percentage of intramuscular fat and ended the grazing season weighing 110 pounds more than NR steers. The NR steers had greater muscling at the end of grazing and greater muscling and yield grade (YG) at the end of finishing. The ANN steer grazing weight advantage carried through to slaughter, and ANN steers' hot carcass weight (HCW) and gross carcass value tended to be greater.

Summary

Forty-eight yearling steers of similar frame score were assigned randomly to an extended-grazing study to compare grazing NR or a sequence of annual forages and evaluate the effect of grazing cover-crop bales as a procedure for extending the grazing season for forage-finished beef. Multiple blizzards, deep snow and drifting created an impossible situation and compromised the study, leaving us with only two options: sell the steers or finish them in the feedlot. The steers were finished at the University of Wyoming's Sustainable Agriculture Research and Extension Center (SAREC) in Lingle and slaughtered at the Cargill Meat Solutions plant in Ft. Morgan, Colo. Finishing beef on forage is time-consuming because the forage-based animal growth rate is approximately one-half that of similar animals fed grain-based finishing diets. Therefore, desirable procedures will ensure consistent growth greater than 2 pounds per day and economically important muscle and fat measurements will increase during the grazing season. Although weather interfered with the forage-finishing component of this investigation, grazing cover-crop bales extended the grazing season from 180 to 221 days. Forage-sequence grazing combined with cover-crop bale grazing supported ADG of 2.14 pounds per day, compared with 1.64 pounds per day for NR steers (*P* = 0.01), and ANN steers were 110 pounds heavier. The annual forage end grazing ultrasound percentage of intramuscular fat (IMF) was greater (*P* = 0.01). Native range steers had greater muscling (rib-eye area-to-hundredweight ratio [REA:CWT]; *P* = 0.04) at the end of grazing. Although not evident at the start of study, during random allotment to NR and ANN grazing treatments, muscling expression among the NR steers increased steadily from the start of the study through grazing to the end of the study. Finishing performance for NR and ANN steers paralleled one another. Except for numerical differences, none of the criteria measured differed statistically. For carcass measurements, ANN steer HCW averaged 85.0 pounds heavier than NR steers, but the difference did not differ (*P* = 0.18). Native range steers were higher yielding (*P* = 0.01) and the muscling relationship expressed as the ratio of REA:HCW was also greater (*P* = 0.04) than the ANN steers. Carcass quality did not differ between the two grazing treatment methods. Gross carcass value for ANN steers exceeded NR steer carcass value by $112.89, which is reflective of the weight margin established between NR and ANN steers during the grazing season.

Introduction

This long-term (10-year) integrated crop and beef cattle investigation focuses on the interrelations of crop production, soil health and beef cattle production. The crop rotation sequence consists of spring wheat, cover crop, corn, field pea-barley and sunflower.

After completing the first five years of the study, we found that marked improvements in soil health reduced and eliminated the need for commercial fertilizer application while production levels were maintained, and in many circumstances, production increased, especially

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for spring wheat grown in the crop rotation. For livestock integration, yearling steers provide the animal basis for vertical integration from birth to slaughter.

One objective of the study was to decrease the mechanical harvest and replace it with animal harvesting as much as possible. Şentürklü et al. (2017) summarized a previous three-year extended-grazing investigation in which yearling steers of two different frame scores (3.8 vs. 5.6) grazed an average of 211 days prior to feedlot entry and were compared with similar, nongrazing steers sent directly to the feedlot and fed for 218 days before slaughter.

Extended-grazing steers spent 82 days in the feedlot. Additionally, the study evaluated two marketing dates: the end of the 211-day grazing period or on the grid when the cattle were finished. The efficiency of the smaller-framed steers had greater net return at the end of grazing, whereas large-framed steers had greater net return at the end of finishing. Others also have documented yearling systems results from weaning to slaughter and reported lower break-even costs and greater net profit (Lewis et al., 1990; Shain et al., 2005).

For the current investigation, corn, field pea-barley and 13 species of cover crops grown in the crop rotation preceded bale grazing of a five-species cover-crop hay (baled in July) as a method for extending the grazing season for forage finishing. The objective was to determine grazing steer performance and the effectiveness of cover crop bale grazing following NR and ANN forage grazing methods on steer muscling, marbling score, yield grade, quality grade, and carcass value.

Experimental Procedures

The North Dakota State University Institutional Animal Care and Use Committee approved animal research procedures used in this study.

Forty-eight yearling crossbred steers (n = 24/treatment/three reps of eight steers; frame score, 4.75 to 4.85) grazed western North Dakota native range (NR) or a forage sequence of the same type of native range and annual forages (ANN: field-pea barley, MasterGraze corn and a 13-species cover crop). For forage finishing, a five-species cover-crop hay was baled in early July (12.9 percent crude protein [CP]) for feeding after grazing (bale grazing).

For NR grazing, steers grazed NR as a common group from spring turnout the first week of May until the third week of July, at which time, the NR treatment group continued to graze NR until Nov. 2. The ANN grazing treatment group grazed the sequence of crops until Nov. 2. On Nov. 2, NR and ANN steers moved to replicated fields and grazed cover-crop hay bales.

Triplicate quarter-meter forage sample collections occurred at the start and end of each forage grazing period. Forage analysis included crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), invitro dry matter disappearance (IVDMD), in vitro organic matter disappearance (IVOMD), calcium (Ca), phosphorus (P) and total digestible nutrients (TDN).

Multiple blizzards, deep snow and drifting made feeding cover-crop bales to the steers impossible. Forage-finish bale grazing discontinued after 41 days. Considering the difficult weather conditions, only two options existed: sell or finish the steers. The steers were finished at the University of Wyoming's Sustainable Agricultural Research Extension Center in Lingle.

Monitoring of steer growth occurred with each forge type change and in the feedlot. The end-point target in the feedlot was based on ultrasound back-fat depth between 0.35 and 0.45 inch. Live animal ultrasound measurements occurred at the end of bale grazing before shipment to the Wyoming feedlot to determine the effect of the grazing method on economically important muscle and fat traits.

Steers were slaughtered at the Cargill Meat Solutions Plant, Fort Morgan, Colo., and grid carcass measurements included hot carcass weight (HCW), fat depth (FD), rib-eye area (REA), marbling score (MS), USDA yield grade (YG), quality grade (QG) and muscle-to-carcass weight ratio (REA: HCW). Gross carcass values were calculated.

Mean separation was determined using the MIXED procedure of SAS. Means with $P \leq 0.05$ differ significantly.

Results and Discussion

Steer growth for NR steers during the 180-day period, from the first week of May to Nov. 2, fluctuated more than for the steers grazing ANN forages, and at the end of bale grazing, the ANN steers weighed 110 pounds more ($P = 0.01$; Table 1).

The NR steers were sensitive to range forage changes related to precipitation. As the NR matured with advancing season, gain declined; however, fall rain stimulated range regrowth and steer gain rebounded during September and October.

Grazing ANN forage sequence crops maintained ADG at ±2 pounds/day throughout the 180-day grazing season because forage maturity among crops selected for the long-term crop rotation are staggered. For example, as field pea-barley grazing was completed, corn matured sufficiently and was ready for grazing. Because cover crop planting occurs after triticale-hairy vetch hay is baled, the cover crop is ready to graze at or near the end of corn grazing.

Forage finishing requires more time for animal growth than the northern Great Plains' growing season allows. Feeding of cover-crop hay prepared in early July occurred after the termination of cover crop grazing.

Cover-crop bale-grazing gain was greater for ANN steers, compared with NR steers ($P = 0.002$), which was unexpected. Gain among ANN steers, compared with NR steers, was 3.27 and 2 pounds/day, respectively. Given the restricted growth nature commonly associated with NR, a compensating gain response, such as the responses reported by Şentürklü et al. (2016) and Choat et al. (2003), was expected.

Overall, for the entire 221-day grazing and bale-grazing period prior to feedlot entry, steer gain and ADG were 362.9 and 1.64, and 472.9 pounds and 2.14 pounds/day for the NR and ANN steers, respectively.

Economically important muscle and fat tissues measured with ultrasound consisted of rib-eye muscle area (REA), percent of intramuscular fat (IMF) and ending marbling score (MS) (Table 2). Rib-eye muscle area increased during the 221-day grazing period, but it did not differ ($P = 0.10$); however, the muscle relationship between REA and weight (REA:CWT) was greater among the NR steers.

ANN steers entered the feedlot weighing 1,246.7 pounds and the NR steers weighed 1,123.8 pounds, a margin of 122.9 pounds (Table 3). Unlike feedlot performance with no variance between treatments, carcass measurements for FD ($P = 0.02$), YG ($P = 0.01$) and REA:HCW ratio ($P = 0.04$) differed (Table 4). The ANN treatment steers consistently grazed higher-quality forage, and growth from cover-crop hay increased the potential for fatter carcasses and more discounts for overweight carcasses. Native range steers had numerically greater MS and greater REA:HCW muscling ($P = 0.04$). The muscling relationship

Table 1. Nutrient analysis of grazed forages and cover-crop bales.

	CP (%)	NDF (%)	ADF (%)	IVOMD (%)	IVDMD (%)	Ca/Phos (%)	TDN (%)
Native Range							
Start	9.7	64.7	35.4	57.5	58.7	0.27/0.13	55.5
End	6.9	38.8	38.9	47.4	48.6	0.31/0.11	52.6
Pea-Barley							
Start	11.0	55.0	30.2	69.6	68.5	0.50/0.23	59.7
End	8.2	67.0	37.9	54.8	54.1	0.37/0.25	53.5
Corn							
Start	7.7	56.6	29.5	78.0	77.6	0.32/0.24	60.1
End	4.6	69.2	38.2	64.7	63.6	0.17/0.20	53.2
Cover Crop							
Start	11.8	50.5	31.5	73.0	69.3	0.72/0.34	58.7
End	12.3	52.8	34.5	64.3	61.9	0.83/0.31	56.4
Cover Crop Bale	12.8	54.4	31.4	72.5	72.3	0.48/0.22	59.0

Table 2. Effect of grazing system on yearling steer grazing performance.

Item	NR[1,2]	ANN[1,2]	SE	*P*-Value[5] Trt[4]
Number steers	24	24		
Steer frame score	4.75	4.85	0.36	0.43
Native Range 75 days				
ADG, lb.	1.69	1.62	0.14	0.72
Field Pea-Barley, 27 days				
ADG, lb.	3.50	2.31	0.62	0.25
Unharvested Corn, 50 days				
ADG, lb.	0.13	2.10	0.29	0.009
Cover Crop (13 species), 28 days				
ADG, lb.	1.91	1.82	0.15	0.70
Bale Grazing, 41 days[3]				
ADG, lb.	2.00	3.27	0.09	0.002
Combined Grazing Periods:				
NR + ANN + Bale Grazing, 221 days				
End weight, lb.	1,179.5	1,314.4	40.17	0.08
Gain, lb.	362.88	472.92	17.67	0.01
ADG, lb.	1.64	2.14	0.08	0.01
Grazing Ultrasound Evaluation				
Start REA, sq. in.	8.2	8.0	0.01	0.18
Start REA: CWT, sq. in.	1.01	0.96	0.023	0.20
End REA, sq in.	10.66	11.51	0.29	0.10
End REA: CWT, sq. in.	0.91	0.88	0.007	0.04
End percent intramuscular fat	3.66	4.25	0.094	0.01
End marbling score[6]	472.0	504.0	11.0	0.10

[1]NR – Native range; ANN – grazing sequence of native range, field pea-barley, unharvested corn and cover crops.
[2]NR and ANN steers grazed NR until July 20, 2016. NR steers continued grazing NR and ANN steers grazed annual forage crops from July 20 to Nov. 2, 2016.
[3]NR and ANN steers were removed from the respective NR and ANN grazing treatments and fed cover crop hay for 41 days before transfer to the University of Wyoming, SAREC feedlot, Lingle.
[4]Trt – Treatment.
[5]Means with $P < 0.05$ differ significantly.
[6]Marbling score: 400 = small; 500 = modest; 600 moderate.

Table 3. Systems feedlot finishing performance of steers placed into feedlot after bale grazing.

Item	NR[1,2,3]	ANN[1,2,3]	SE	*P*-Value[5] Trt[4]
Number steers[3]	24	24		
Days on feed	119.00	119.00		
Feedlot start wt., lb.	1,123.75	1,246.67	37.66	0.11
Feedlot end wt., lb.	1,500.80	1,618.40	57.47	0.22
Feedlot gain, lb.	377.05	371.73	20.04	0.85
Feedlot ADG, lb.	3.14	3.09	0.17	0.84
DM Intake, lb.	24.83	25.24	1.49	0.86
Gain:feed, lb.	0.127	0.124	0.0049	0.67
Feed cost/steer, $	210.78	213.94	11.55	0.86
Feed cost/lb. gain, $	0.5597	0.5763	0.022	0.60
Total feedlot cost/steer, $	346.11	351.93	12.71	0.76
Total feedlot cost/lb. gain, $	0.9233	0.9467	0.038	0.40

[1]NR – Native range; ANN – grazing sequence of native range, field pea-barley, unharvested corn and cover crops.
[2]NR and ANN steers grazed NR until July 20, 2016. NR steers continued grazing NR and ANN steers grazed annual forage crops from July 20 to Nov. 2, 2016.
[3]NR and ANN steers were removed from the respective NR and ANN grazing treatments and fed cover crop hay for 41 days before transfer to the University of Wyoming, SAREC feedlot, Lingle.
[4]Trt – Treatment.
[5]Means with $P < 0.05$ differ significantly.

Table 4. Effect of grazing system on closeout carcass characteristics.

Item	NR[1,2,3]	ANN[1,2,3]	SE	*P*-Value[5] Trt[4]
Number steers	24	24		
HCW, lb.	931.0	1,016.0	35.66	0.18
Fat depth, in.	0.37	0.44	2.35	0.02
REA, sq in.	14.43	14.70	0.35	0.63
REA : HCW ratio, sq in.	1.55	1.45	3.23	0.04
Marbling score[6]	546.7	530.4	25.58	0.44
USDA YG	2.38	2.71	0.058	0.01
QG Choice or better, %	100.00	100.00		0.31
Gross carcass value, $	1,944.37	2056.44	55.46	0.22

[1]NR – Native range; ANN – grazing sequence of native range, field pea-barley, unharvested corn and cover crops.
[2]NR and ANN steers grazed NR until July 20, 2016. NR steers continued grazing NR and ANN steers grazed annual forage crops from July 20 to Nov. 2, 2016.
[3]NR and ANN steers were removed from the respective NR and ANN grazing treatments and fed cover crop hay for 41 days before transfer to the University of Wyoming, SAREC feedlot, Lingle.
[4]Trt – Treatment.
[5]Means with $P < 0.05$ differ significantly.
[6]Marbling score: 400 = small; 500 = modest; 600 moderate.

identified for the NR steers at the end of grazing remained consistent to the end of finishing.

Gross carcass value for ANN steers was numerically greater ($1,944.37 vs. $2,056.45), but it did not differ ($P = 0.22$). Although no statistical difference was identified, results reported by Şentürklü et al. (2014; 2016) showed weight margins among groups entering the feedlot did not change appreciably by the end of the finishing period and gross carcass value was routinely greater.

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The effect of protein concentrations in finishing diets on animal performance and carcass characteristics of steers

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The objective of this study was to evaluate the effect of four crude protein (CP) concentrations (7, 11, 16 and 21 percent CP) in finishing cattle diets on growth performance and carcass characteristics. Cattle fed the 7 percent CP diet had reduced average daily gain, dry-matter intake, gain-to-feed ratio (gain:feed), hot carcass weight, marbling score and back fat thickness, with no differences among the other treatments. This indicates that feeding diets containing 11 percent or greater CP is necessary to optimize growth performance and carcass characteristics.

Summary

One-hundred thirty-two steers (698 pounds average initial body weight [BW]) were utilized to determine the effect of four different crude protein (CP) concentrations in finishing diets on animal performance and carcass characteristics. Steers were stratified by initial BW across five pens and randomly assigned to one of the four dietary treatments (n = 33 per treatment) containing 7, 11, 16 and 21 percent CP. Corn silage and wheat straw were offered at 10 and 5 percent of dry matter (DM) in all diets as the roughage source. Urea was used as the supplemental protein source for the 11 percent CP diet, and urea and dried corn distillers grains with solubles (DDGS) were used as the supplemental protein sources for diets containing 16 and 21 percent CP. Corn oil was provided in the first three diets to match the amount of oil of the diet containing 21 percent CP. The Insentec feeding system was used to measure individual feed intake. Steers had an average finished weight of 1,320 pounds and were marketed in five groups at 172 days (n = 15), 179 days (n = 40), 186 days (n = 44), 195 days (n = 9) and 200 days (n = 24). Steers fed the 7 percent CP had reduced ($P \leq 0.05$) average daily gain and DM intake (pounds) when compared with diets with 11, 16 and 21 percent CP. Steers fed the 7 percent CP diet had greater ($P \leq 0.05$) gain:feed in comparison with the steers fed 11 and 21 percent CP. Besides, gain:feed tended to be greater ($P \leq 0.10$) in steers fed the 16 percent CP, compared with 7 percent CP. In addition, steers fed the 7 percent CP diet had lower ($P \leq 0.05$) hot carcass weight (HCW), marbling score, back fat, and kidney, pelvic, and heart fat (KPH) in comparison with steers fed the other three diets. However, rib-eye area did not differ among the treatments. These data indicate that feeding diets containing 11 percent or greater CP is necessary to optimize growth performance and carcass characteristics.

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Introduction

Feed costs represent the most expensive component in a feedlot production system (Lanna et al., 1999). In this scenario, the dietary protein source is usually the nutrient that has greater cost per unit, being responsible for a large contribution to the ration cost and, ultimately, the production system. Protein supplementation to ruminants often results in greater animal performance, which makes protein a limiting nutrient for production (Medeiros and Marino, 2015).

North Dakota has a large production of corn distillers grain due to multiple ethanol plants. Swanson et al. (2014) described that feeding DDGS to finishing cattle improved feed efficiency. Previous results have shown that DDGS is an economical and palatable feed ingredient for finishing lamb diets, serving as a good supplemental protein source (Held, 2006).

As reported by Galyean (2014), the typical percentage of crude protein in finishing cattle diets exceeds 12 percent of the diet (dry-matter basis), which is greater than the amount predicted from a factorial system for calculating protein requirements. Increasing the availability of crude protein in typical industry diets potentially has resulted in increased needs for nitrogen (N) by the ruminal microbes (Galyean, 2014).

Given the above, research is needed to investigate production responses to protein supplementation. The objective of this study was to evaluate the effect of four crude protein concentrations in finishing cattle diets on animal performance and carcass characteristics.

Experimental Procedures

The NDSU Animal Care and Use Committee approved all procedures with the animals. One hundred thirty-two steers (698 pounds of average initial BW) predominantly of Angus, Simmental and Shorthorn breeding were blocked by initial BW and housed within five pens (n = 26 to 32 animals/pen; n = 33 animals/treatment) equipped with Insentec automated feeding stations at the NDSU Beef Cattle Research Complex.

Diets were formulated using the Beef Cattle Nutrient Requirements Model (2016) software to provide four different crude protein concentrations to the steers (7, 11, 16 and 21 percent CP). The availability of grams per day of estimated metabolizable protein was formulated to differ by a similar amount between adjacent dietary treatments.

Corn silage and wheat straw were offered at 10 and 5 percent of dry matter for all diets as the roughage source. Urea was used as the supplemental protein source for the diet with 11 percent CP and urea, and dried distillers grains with solubles (DDGS) were used as the supplemental protein sources for diets with 16 and 21 percent CP. Corn oil was provided in the first three diets to match the amount of oil among the four treatments (Table 1).

Diets were offered for ad libitum intake, and the animals had free access to water. A dietary transition period of 28 days was used. During that period, the steers were adapted to the final diets by transitioning from 60 to 90 percent concentrate diets. The animals received implants with 4 milligrams (mg) of estradiol and 20 mg of trenbolone acetate (Revalor-XS; Merck Animal Health, Whitehouse Station, N.J.).

Body weight measurements were taken on two consecutive days prior to the beginning of the experiment and every 28 days throughout the experiment. Final BW was estimated by a linear regression (days on feed times average daily gain plus the BW intercept). Average daily gain was calculated by regressing BW on days of the experiment.

As described by Swanson et al. (2014), individual feed intake measurements were taken using an automated feeding system (Insentec; Hokofarm B.V. Repelweg 10, 8316 PV Marknesse, The Netherlands). Each pen contained eight troughs, and each diet was delivered to two troughs per pen. Diet samples were collected weekly and diet DM was measured weekly during the entire experimental period.

Steers were fed until they achieved an average finished weight of 1,320 pounds and were marketed in five groups at 172 days (n = 15), 179 days (n = 40), 186 days (n = 44), 195 days (n = 9) and 200 days (n = 24). Carcass characteristics were provided by the commercial slaughter facility; hot carcass weight data were taken right after slaughter

Table 1. Diet and nutrient composition of the dietary treatments.

	Treatment			
Ingredient, % of DM	**7% CP**	**11% CP**	**16% CP**	**21% CP**
Corn	77.7	77.7	57.1	36.0
Corn silage	10.0	10.0	10.0	10.0
Wheat straw	5.00	5.00	5.00	5.00
DDGS	–	–	21.8	44.0
Corn oil	2.30	2.30	1.10	–
Urea	–	1.50	1.50	1.50
Limestone	1.80	1.80	1.80	1.80
Salt	0.24	0.24	0.24	0.24
Fine ground corn	2.87	1.37	1.37	1.37
Vitamin premix[1]	0.01	0.01	0.01	0.01
Trace mineral premix[2]	0.05	0.05	0.05	0.05
Monensin premix[3]	0.02	0.02	0.02	0.02
Tylosin premix[4]	0.01	0.01	0.01	0.01
Nutrients[5]				
Dry matter (DM), %	73.3	73.8	74.2	74.1
Organic matter, % of DM	95.2	95.2	94.2	93.5
Predicted metabolizable protein supply[6], g/d	627.9	912.1	1195.5	1475.9
Crude protein, % of DM	7.84	11.7	17.2	20.9
Neutral detergent fiber, % of DM	25.9	24.9	31.0	34.7
Acid detergent fiber, % of DM	10.7	10.3	12.6	13.8
Fat (ether extract), % of DM	4.89	4.80	5.02	4.57
Calcium, % of DM	0.54	0.56	0.57	0.56
Phosphorus, % of DM	0.27	0.26	0.42	0.53

[1]Contained 48,510 1,000 International Units per kilogram (kIU/kg) vitamin A and 4,630.5 kIU/kg vitamin D.

[2]Contained 3.62 percent calcium (Ca), 2.56 percent copper (Cu), 16 percent zinc (Zn), 6.5% iron (Fe), 4% manganese (Mn), 1,050 milligrams per kilogram (mg/kg) iodine (I) and 250 mg/kg cobalt (Co).

[3]Contained 176.4 grams (g) Monensin/kg premix.

[4]Contained 88.2 g Tylosin/kg premix.

[5]Average of weekly samples.

[6]Predicted through National Academies of Sciences, Engineering, and Medicine (2016).

of the animal, whereas marbling score, subcutaneous fat thickness at the 12th rib (back fat), rib-eye area (REA), and kidney, pelvic and heart fat (KPH) were taken after carcass chilling in a cooler.

Data were analyzed as a completely randomized design with blocking factor (slaughter group) using General Linear Model (GLM) procedure of SAS. Differences among treatments were determined using the least significant difference approach.

Results and Discussion

Among the four treatments, steers fed the diet containing 7 percent CP resulted in lower ($P \leq 0.05$) average daily gain (ADG; Table 2); however, the other three treatments did not differ in ADG, which likely indicates an excess supply of crude protein in the 16 and 21 percent CP diets.

Dry-matter intake (pounds) was lower ($P \leq 0.05$) in steers with the 7 percent CP diet in comparison with steers in the other treatments. This effect may be caused by the palatability of the diet or because they gained less weight and thus weighed less during much of the experiment.

Steers fed the 21 percent CP diet had less ($P \leq 0.05$) DM intake, compared with cattle fed the 11 or 16 percent CP diet, potentially because of decreased palatability and/or an increase in the incidence of subacute ruminal acidosis. In addition, steers fed the 7 percent CP diet had lower ($P \leq 0.05$) gain:feed (G:F) than steers fed diets containing 11 and 21 percent CP.

We also observed a tendency for steers fed the 7 percent CP diet to have a lower G:F than the steers on the 16 percent CP diet. Overall, these results suggest that the 7 percent CP diet was deficient in CP, which may have slowed muscle development, affecting directly growth and feed efficiency in the animal.

Similarly, steers fed the 7 percent CP diet had lower ($P \leq 0.05$) HCW and marbling scores in comparison with steers on the other dietary treatments. Lower HCW is directly related to less profit especially if combined with lower marbling score, which results in lower quality grade.

Back fat and KPH also were lower ($P \leq 0.05$) in the steers fed the 7 percent CP diet, compared with steers on the other treatments. This likely was because the deficiency in protein (7 percent CP) in the diet reduces growth, resulting in a longer period to achieve the mature weight and desirable fat deposition.

In conclusion, these data indicate that feeding diets containing 11 percent or greater CP is necessary to optimize growth performance and carcass characteristics.

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Table 2. Effects of dietary protein levels on animal performance and carcass of finishing cattle.

	Treatment[2]					
Item	7% CP	11% CP	16% CP	21% CP	SEM	*P*-value
Average daily gain, lb./day	3.25[a]	3.72[b]	3.64[b]	3.63[b]	0.061	<0.01
Dry-matter intake, lb.	20.4[a]	21.8[b]	22.0[b]	21.4[b]	0.378	0.01
Dry-matter intake, % BW	3.05	2.98	3.03	2.98	0.045	0.53
Gain:feed	0.15[ac]	0.17[b]	0.16[bd]	0.17[b]	0.003	<0.01
Hot carcass weight, lb.	759[a]	805[b]	815[b]	822[b]	8.149	<0.01
Marbling score	431[a]	481[b]	500[b]	479[b]	17.25	0.01
Rib-eye area, in.^{2}	13.0	13.1	13.2	13.3	0.222	0.59
Back fat, in.	0.36[a]	0.48[b]	0.53[b]	0.52[b]	0.026	<0.01
Kidney, pelvic and heart fat, %	1.81[a]	1.92[b]	1.98[b]	1.92[b]	0.032	<0.01

[1]SEM = Standard error of the mean.

[2]7 percent CP (n = 33), 11 percent CP (n = 33), 16 percent CP (n = 33), 21 percent CP (n = 33). When overall *p*-value <0.05, means in a row not sharing a common letter (a,b) differ ($P \leq 0.05$) from each other. When overall *p*-value <0.10, means in a row not sharing a common letter (c,d) tend to differ ($P \leq 0.10$) from each other.

Effects of growth-promotant technologies during beef finishing on activation of the calpain proteolytic system in sectioned aged beef steaks

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The results from the present work indicate that degradation of muscle protein during postmortem aging is less in strip steaks from heifers given growth promotants (implants and beta-adrenergic agonists) during finishing, which may help explain measured differences in tenderness. However, differences in activity of calpain 1 and calpastatin, a calpain inhibitor, were not observed in strip steaks at day 3 and day 14 of aging. Calpain 2 activity was different in the middle and lateral portion of the strip steaks at day 3 of aging, indicating that within a retail cut, rates of aging differ. Evaluation of calpain system activity may need to be conducted earlier postmortem to confirm or reject the influence of growth-promoting technologies on its activation and role in postmortem protein degradation and ultimately beef tenderness.

Summary

The objective of this study was to determine if postmortem protein degradation in beef steaks due to the activation of the calpain system during aging is the reason for decreased tenderness in beef cattle given implants and fed zilpaterol hydrochloride (ZH) during finishing. Calpain and calpastatin activity and protein degradation products in aged beef strip steaks were evaluated. Results indicate that cattle given anabolic implants and beta-adrenergic agonists show a decrease in troponin-T degradation at day 14 of aging, which relates to decreased tenderness. However, both calpain 1 and calpastatin activity were not different at the time points evaluated and may need to be evaluated earlier postmortem to confirm or negate their influence on postmortem protein degradation. Interestingly, calpain 2 activity was decreased in the cattle given growth promotants, compared with control cattle. Calpain 2 has not been implicated previously as having a role in beef aging and possibly has more of a role in regulating muscle growth during finishing rather than postmortem influences on tenderness.

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Introduction

Beta-adrenergic agonists and anabolic implants are growth-promoting technologies that are used commonly in beef production. The use of these technologies has been proven to increase lean meat yields when utilizing similar inputs. However, implants have been shown to reduce beef tenderness (Roeber et al., 2000). Likewise, the two FDA-approved beta-adrenergic agonists, zilpaterol hydrochloride and ractopamine, also may cause a decrease in tenderness (Arp et al., 2013, Scramlin et al., 2010).

In this study, when beta-adrenergic agonists were utilized in conjunction with an implant, the combination yielded less tender meat than just implanting at day 3 and day 14 of aging (Ebarb et al., 2016). Differences in meat tenderness can be attributed to many intrinsic muscle factors, such as collagen content, contractile state and protein degradation.

Protein degradation has the biggest influence on tenderness during aging and mainly occurs due to activation of the calpain system during early postmortem. The influence of growth-promoting technologies on the calpain system needs further understanding and clarification in order to better understand changes in postmortem protein degradation and subsequent tenderization during aging.

Experimental Procedures

Crossbred heifers (n = 15) were blocked by weight and randomly assigned to one of three treatments: 1) no implant or ZH (CON), 2) implant, no ZH (IMP) and 3) implant and ZH (IMP+ZH). Cattle were fed in individual pens at Kansas State University and were fed a similar diet. Feed was delivered once daily to allow *ad libitum* access to feed. Bunks were managed to leave a minimum amount of unconsumed feed daily.

On day zero, heifers (IMP and IMP+ZH) were given an implant containing 200 milligrams (mg) of trenbolone acetate and 20 mg of estradiol (Component TE-200; Elanco Animal Health, Greenfield, Ind.). On day 50, 8.3 parts per million (ppm) of zilpaterol hydrochloride (ZH; Zilmax, Merk Animal Health) was included in the finishing ration (IMP + ZH). It was included for 21 days, with a three-day withdrawal prior to slaughter.

Heifers were shipped 284 miles to be harvested in a commercial abattoir (Tyson Fresh Meats, Holcomb, Kan.) on day 75. Following a 36-hour chill, strip loins (Institutional Meat Purchase Specifications 180) were removed from one side of the carcass.

Strip loins that had aged for three and 14 days at a temperature of 40 F were cut into steaks, frozen and shipped on dry ice overnight to the North Dakota State University meat science laboratory (Fargo, N.D.). Steaks were thawed overnight at 40 F. After performing objective color (L*, a* and b* values) and pH measurements, steaks were cut into three sections (lateral, lateral/medial and medial), and they underwent protein extraction for analysis.

Proteins were extracted and measured by western blot for troponin-T (TnT) degradation and heat shock protein 70 abundance. Calpain 1 and 2 activity was determined by casein zymograms, and calpastatin activity was determined by casein assay.

Results and Discussion

Minolta L*, a* and b* values that measure lightness to darkness, redness and yellowness, respectively, were not different ($P > 0.19$) among treatments, aging days or location. Additionally, meat pH did not differ across variables ($P > 0.27$).

Six troponin-T (TnT) bands ranging from 40 kilodaltons (kDa) to 27 kDa (Table 1; where bands 1

Table 1. Interactive least squares means of troponin-T Western blot bands (percentage of total density) of sectioned beef strips steaks from heifers treated with growth-promotant technologies during finishing.

	Treatment									
	Medial			Medial/Lateral			Lateral			
Item[1]	Control	IMP[2]	IMP+ZH[3]	Control	IMP	IMP+ZH	Control	IMP	IMP+ZH	SEM[4]
Band 1 (40 kDa)[5]										
Day 3	46.15	67.48	54.45	53.35	57.20	53.84	44.03	56.94	53.51	8.81
Day 14	29.50	26.36	45.46	25.86	41.45	47.37	26.04	38.94	30.78	8.81
Band 2 (38 kDa)[5,6]										
Day 3	9.97	12.11	19.08	10.71	13.43	17.13	13.20	16.28	19.34	2.45
Day 14	6.78	7.35	14.31	5.62	11.26	14.83	6.78	10.64	12.87	2.45
Band 3 (36 kDa)[5,8]										
Day 3	14.99	6.44	6.41	11.42	10.35	10.19	12.89	9.05	8.28	2.36
Day 14	14.52[ab]	17.86[a]	9.58[b]	17.64[a]	14.54[ab]	10.64[b]	17.78[a]	12.39[b]	14.21[ab]	2.36
Band 4 (34 kDa)[5]										
Day 3	16.16	9.53	13.61	16.17	13.88	16.38	18.05	13.26	14.12	4.66
Day 14	22.14	28.49	24.38	30.42	22.84	24.75	23.51	23.70	33.10	4.66
Band 5 (30 kDa)[5,7]										
Day 3	9.17	2.62	4.40	6.01	3.17	1.10	8.93	2.58	2.66	3.93
Day 14	18.23[a]	14.60[a]	2.44[b]	14.06[a]	6.38[ab]	1.27[b]	13.00[a]	10.26[a]	6.10[ab]	3.93
Band 6 (27 kDa)[5,7,8]										
Day 3	2.05	0.71	1.01	1.06	0.78	0.72	1.37	0.61	1.23	0.96
Day 14	6.91[a]	2.74[b]	1.87[b]	4.79[a]	1.63[b]	0.64[b]	3.66[ab]	2.26[ab]	1.84[b]	0.96

[1]Immunoreactive bands for troponin-T western blot. Bands 1 and 2 are considered as intact protein and bands 3 through 6 are considered as degradation products.

[2]Heifers were implanted with 200 mg trenbolone acetate and 20 mg estradiol on day zero of feeding.

[3]ZH = zilpaterol hydrochloride. Heifers were implanted with 200 mg trenbolone acetate and 20 mg estradiol on day zero of feeding and supplemented with 8.3 ppm of ZH for the last 20 days of feeding, followed by a three-day withdrawal period.

[4]Standard error of mean.

[5]Day of aging, $P < 0.05$; [6]Treatment, $P < 0.05$; [7]Day of aging x treatment, $P < 0.05$.

[8]Day of aging x treatment x location, $P < 0.05$.

[a,b]Means within a row differ, $P < 0.05$.

and 2 were considered intact and bands 3 through 6 were considered degradation products) were analyzed on steaks from three days and 14 days of aging. The amount of intact TnT, as well as the amount of degradation products, are indicators of overall protein breakdown and highly correlated to the Warner-Bratzler shear force measurement of tenderness (Sun, et al., 2014; Huff-Lonergan et al., 1996).

As expected, degradation products increased during aging (*P* < 0.05). The IMP+ZH treatment had greater intact TnT (band 2) and less degraded TnT (band 6), indicating less overall protein degradation in steaks from cattle given growth-promoting treatments during finishing.

Within a steak, the medial portion had more degradation in CON, compared with the middle or lateral portions, indicating variation of aging within a single retail cut. This is likely the result of the rate of cooling the muscle postmortem because the interior section of the muscle had less degradation product than the two outer sections.

We found no effect (*P* > 0.05) on either of the 65 or 67 kDa bands of heat shock protein 70 by the treatments, aging day or location. Heat shock proteins have been shown to play a protective role over myofibrillar proteins during aging.

Calpain activities did not differ (*P* > 0.05) among treatment, aging days or section. However, we found a treatment by section interaction (*P* = 0.03) in calpain 2 measurements in which the lateral/medial section of IMP+ZH had a smaller clear zone than the lateral/medial sections of CON and IMP (Table 2), indicating lower activity level. Additionally, the lateral section of CON had a larger calpain 2 clear zone than the medial section of CON and lateral section of IMP+ZH, indicating a higher activity level.

Calpain 2 activity tended to be reduced in cattle fed ZH while calpain 1 activity was insubstantial by day 3 in all treatments, which is possibly due to different rates of cooling within the muscle postmortem.

Calpain 1, a calcium-dependent protease, has been implicated to be the main driver of postmortem protein degradation during aging. The differences in calpain 1 were not measured in this study due to the observed differences in protein degradation and beef tenderness. However, calpain 1 is active very early postmortem, and the time points measured in this study may have missed the time frame in which differences in calpain 1 activity could be elucidated.

Calpain 2 often has been described as having no influence on postmortem protein degradation because its activity does not seem to change through time. However, the treatment and location differences observed in this study indicate calpain 2 may be influenced by growth promotants. The role of calpain 2 in aging still needs to be determined.

In the current study, calpastatin activity was not different (*P* > 0.05) among treatment, aging days or section. Calpastatin is the inhibitor of calpains. Increases in calpastatin activity are highly correlated with decreases in tenderness (Lonergan et al., 2001), indicating the calpastatin can inhibit the proteolytic activity of calpain 1.

Table 2. Interactive least squares means of calpastatin and calpain activity of sectioned beef strips steaks from heifers treated with growth-promotant technologies during finishing.

	Treatment									
	Medial			Medial/Lateral			Lateral			
Item[1]	Control	IMP[2]	IMP+ZH[3]	Control	IMP	IMP+ZH	Control	IMP	IMP+ZH	SEM[4]
Calpastatin										
Day 3	0.97	1.22	1.42	0.99	1.15	1.59	0.89	1.16	1.50	0.36
Day 14	0.86	0.87	1.39	0.78	0.83	1.22	0.88	1.01	1.24	0.36
Calpain 1 (Day 3)	0.004	0.039	0.033	0.006	0.018	0.055	0.005	0.017	0.076	0.022
Calpain 2 (Day 3)[5]	1.01[b]	0.93[b]	0.93[b]	1.09[ab]	1.09[ab]	0.80[c]	1.16[a]	1.12[ab]	0.87[bc]	0.10

[1]Calpastatin activity = units/gram sample; calpain activity = area of clear zone from casein zymogram gel.

[2]Heifers were implanted with 200 mg trenbolone acetate and 20 mg estradiol on day zero of feeding.

3ZH = zilpaterol hydrochloride. Heifers were implanted with 200 mg trenbolone acetate and 20 mg estradiol on day zero of feeding and supplemented with 8.3 ppm of ZH for the last 20 days of feeding, followed by a three-day withdrawal period.

[4]Standard error of mean.

[5]Treatment x location, *P* = 0.03.

[a,b]Means within a row differ, *P* < 0.05.

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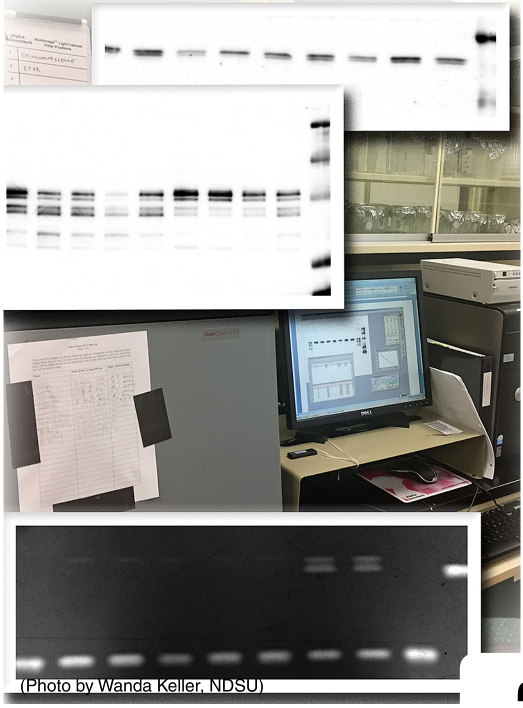
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