
(Photo by Skip Anderson, NDSU)

2021 North Dakota Livestock Research Report

This is the 10th year that I have been the coordinator and editor of this report and I still enjoy this activity because it is an important means to report our research findings to producers and industry personnel across North Dakota and beyond.

The report has expanded its scope through the years, evolving from the North Dakota Beef Report and the North Dakota Beef and Sheep Report, and now to the North Dakota Livestock Research Report. Besides providing current research results to those who are interested, I hope that this report will continue to remind us of the quality and breadth of our livestock research, and Extension and teaching programs in North Dakota. I want to assure you that we are doing our best to provide relevant research results and Extension programming to support the beef cattle and sheep industries in North Dakota in the near and long term.

The livestock programs at the North Dakota Agricultural Experiment Station's Main Station in Fargo and the Research Extension Centers across North Dakota are dedicated to serving the producers and stakeholders in North Dakota. This report includes a broad range of research that provides producers and stakeholders with one document that contains livestock-related research conducted at NDSU each year.

For this year's report, we again are including some selected Extension programming updates. As you will see, our Extension programming covers a broad range of topics and in many cases is tightly linked with our research programs. Please consider participating in Extension events or accessing Extension publications and materials in the coming year.

I want to again thank Ellen Crawford and Deb Tanner for their great assistance in editing and formatting so that we can publish a great statewide report. Also, thanks to the contributors to the report, and to the staff and students who help with livestock research, teaching and Extension activities.

Finally, thanks to the funders of the grants that help fund the research projects and students/staff working on the projects. We truly appreciate your contributions to our research programs. Without this support, the research would not be possible.

If you should have any questions about the research reported in this report, please do not hesitate to contact me or any of the authors of the individual reports. Thanks for your encouragement and support of livestock research in North Dakota.

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Forage mineral concentration with patch-burn grazing

Megan R. Wanchuk,[1] Devan A. McGranahan,[2] Kevin K. Sedivec[3] and Kendall C. Swanson[4]

The objective of this study was to determine if patch burning can increase mineral concentration of forage in rangeland pastures. Forage calcium, phosphorus, copper and zinc concentration was greater in burned areas than in unburned areas, which may benefit livestock performance.

Summary

Patch-burn grazing is a livestock management practice that provides a wide range of benefits to ecosystem conservation and livestock production. Mineral nutrition is important for livestock health and performance; however, the impact fire has on mineral concentration of forages in the northern Great Plains remains unknown. In this study, we determined how burning affects the mineral concentration of available forage through the growing season. Data were collected on mixed-grass rangeland at the Central Grasslands Research Extension Center in south-central North Dakota during 2017 and 2018. Vegetation was clipped from recently burned patches and unburned patches on thin loamy ecological sites at the same sampling locations in the spring and late summer. All samples were analyzed for calcium, phosphorus, copper and zinc concentration. Burning increased forage mineral concentration across all minerals. Copper, phosphorus and zinc were greater in burned patches, compared with unburned patches, at the beginning and end of the growing season. Calcium concentration was not different between burned and unburned patches during the spring but was greater in burned patches by late summer. Increased mineral concentration in forage on burned areas has the potential to reduce mineral supplementation costs and improve cow performance through enhanced immune function and reproduction.

Introduction

Patch-burn grazing is a rangeland management practice that concentrates grazer activity in recently burned patches within large rangeland pastures (Fuhlendorf et al., 2017). Patch burning benefits livestock production by altering the physiology of vegetation, which creates an increased crude protein content and a reduced fiber content (Spiess et al., 2020). Patch burning also maintains or increases cattle weight gains (Scasta et al., 2016) and buffers livestock production during drought (Spiess et al., 2020).

Mineral nutrition is an important consideration to maximize cattle production and maintain ranch sustainability through influence on reproduction, health and growth (Suttle, 2010). However, rangeland forage does not always satisfy the mineral requirements of grazing cattle throughout the grazing season, decreasing forage utilization and performance. While free-choice mineral supplementation can be used to meet requirements of grazing animals, this practice is costly for producers and results in high variability of intake between animals.

Although minerals are an important component of livestock nutrition, no studies have examined the impacts of patch-burn grazing on forage mineral concentration. Therefore, the objective of this study was to determine if patch burning increases mineral concentration of forage in rangeland pastures.

Experimental Procedures

This study was conducted at the Central Grasslands Research Extension Center in south-central North Dakota. Pastures are mixed-grass prairie consisting of native and introduced C3 grasses, native C4 grasses, forbs, legumes and shrubs.

Samples were collected in 2017 and 2018 on four pastures managed with patch-burn grazing. These pastures underwent a spring burn treatment (April) in which a quarter of the pasture (40 acres) is burned each spring, creating a four-year fire return interval.

Forage sampling occurred on recently burned and unburned patches during the spring (May) and late summer (September), which corresponded to when cattle started the grazing season and within a month of the end of the grazing season. Patches classified as recently burned received a fire treatment in the sampling year.

To determine forage mineral content at the beginning and end of the grazing season, above-ground biomass was clipped from a 25-centimeter (cm) by 25-cm frame during late spring (May-June) and late summer (August-September). All

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plant material above the crown was clipped to minimize contamination from soil and litter but still include the live and standing dead material. Samples were collected from thin loamy ecological sites to minimize the effect of different soil type on mineral content.

After clipping, samples were dried for 48 hours at a temperature of 60 C in a forced air oven, ground with a Willey Mill using a 1-milliliter (mm) screen and stored in bags for chemical analysis. Samples were analyzed for calcium (Ca), phosphorus (P), copper (Cu) and zinc (Zn) using atomic absorption spectrophotometry.

Results and Discussion

Phosphorus, Cu and Zn concentration were greater during late spring and late summer in the forage regrowth after fire, as compared with forage in unburned patches (Figure 1). In both years, Ca was only greater in the recently burned patch during late summer sampling.

Forage Cu concentration in the recently burned patch was variable between years but remained higher than in unburned patches. Year to year difference is apparent in P, Cu and Zn with the late-season, recently burned mineral concentration being much lower in 2018 than 2017.

Patch-burn grazing increased forage mineral concentration in recently burned patches for the extent of the grazing season. Increases in forage mineral concentration following fire can be attributed to reduced age of plant tissue, increased leaf-to-stem ratio and nutrients distributed over less biomass in post-fire vegetation (Van de Vijver et al., 1999).

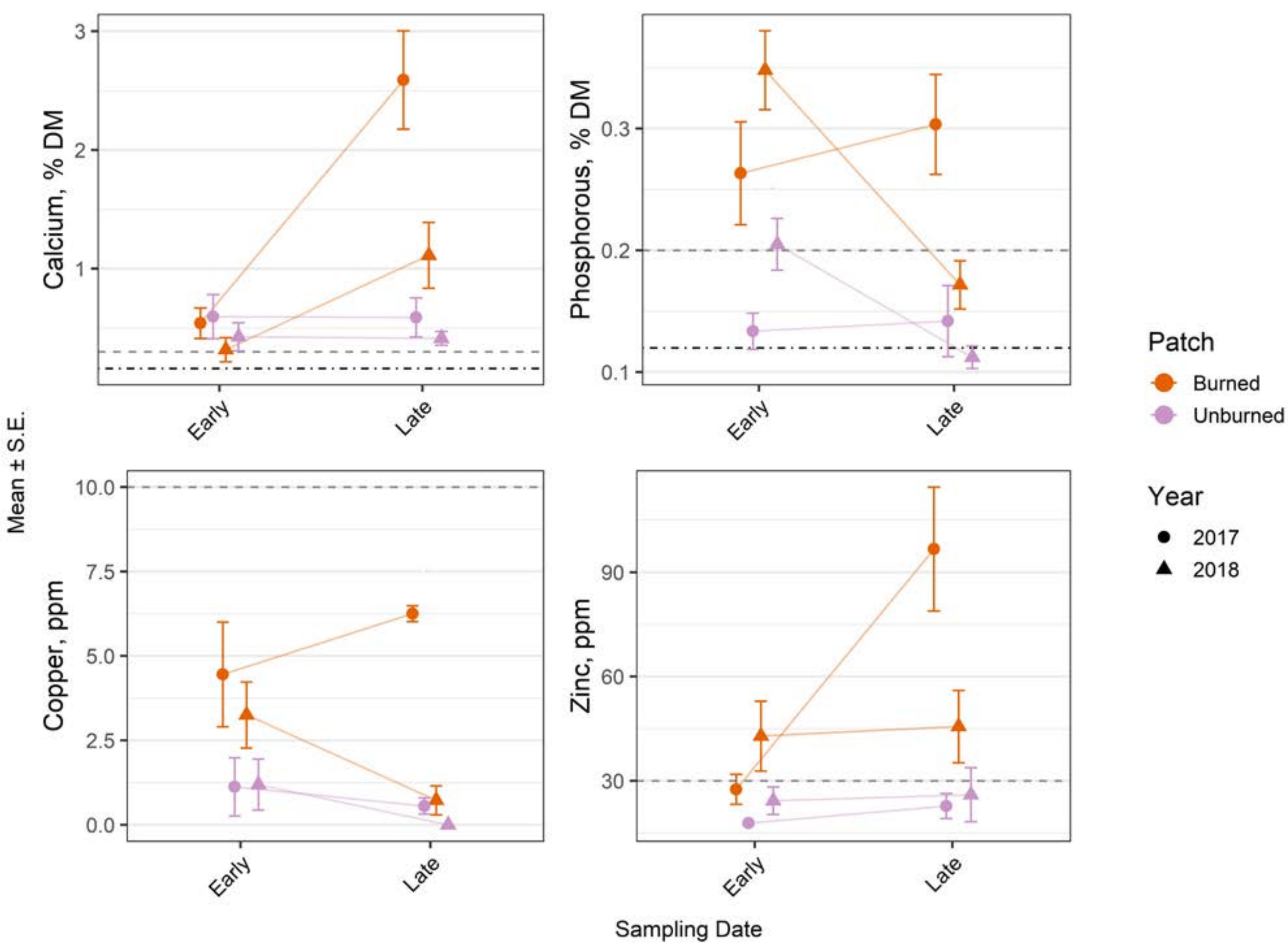

Figure 1. Average mineral concentration of forage in burned and unburned patches in patch-burn grazing pastures. Horizontal lines indicate recommended mineral concentrations based on NASEM, 2016, Nutrient Requirements of Beef Cattle. Calcium and P recommendations are based upon a 572-kilogram (kg) cow with 8 kg/day peak milk production and 40 kg calf birth weight. The gray dashed line in the calcium and phosphorus represents recommendations for April calving during the early grazing season and the black dash-dot line represents late summer recommendations. The dashed line for copper and zinc represents the general season-long minimum recommendations.

Mineral concentration in the recently burned patch was generally adequate to meet recommended levels of Ca, P and Zn for lactating cows based on an April-calving 1,300-pound cow (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016). Forage in the unburned patch was often below recommended levels for P and Zn.

Requirements for Ca and P are dependent upon cow size, physiological state and milk production. Therefore, requirements will change between individual animals and throughout the grazing season.

What is important to note is that meeting the recommended mineral levels does not indicate that requirements are being met. Factors such as the location of the mineral in the plant, chemical form and mineral interactions all influence the bioavailability of minerals. Copper was deficient based on recommended levels (NASEM, 2016) across both treatments, and higher concentration in the burn patch might not be substantial when antagonistic interaction with molybdenum, sulfur and iron are considered.

Our results suggest that patch-burn grazing can increase mineral concentration of forage in the recently burned patch. Increased mineral concentration in forage on burned areas has the potential to reduce mineral supplementation costs and increase cow performance. Understanding mineral trends may provide producers with insight into the best supplementation strategies and mineral formulations to maximize performance and profitability.

Acknowledgments

The authors acknowledge the North Dakota State University Central Grasslands Research Extension Center and North Dakota Agricultural Experiment Station for financial support of this project. Thanks to Micayla Lakey and the staff at the Central Grasslands Research Extension Center for assistance with forage collection.

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Silage quality and nutrient content of silage corn hybrids ensiled at varying maturities and moisture contents

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Twelve new early and late-maturing silage corn hybrids (relative maturity from 94 to 111 days) were ensiled in laboratory silos at moisture concentrations from 60% to 72% and evaluated for nutrient concentration and quality. Generally, ensiling corn hybrids at moisture concentrations from 60% to 72% produced good-quality silage. However, silage quality (silage pH, and concentrations of lactic acid, acetic acid and total acids) increased with increasing moisture content. Reducing variation in moisture content by selecting silage corn hybrids with a narrower range in relative maturity would lead to more uniform silage quality.

Summary

Silage quality of early and late-maturing silage corn hybrids ensiled at varying maturities and moisture contents was evaluated. Selected corn hybrids were Mycogen 0526AM, Mycogen 1247AMXT, Mycogen TMF94L37, Dairyland 3099RA, Dairyland 3211, Croplan CP3899VT2P, Croplan CP4100SV2P, Croplan CP5000SAS3122, NK E105, Pioneer P0157AMXT, Pioneer P9608Q and Legacy L5467. Three replicates of each hybrid were ensiled in laboratory silos and stored at 21 C in a temperature-controlled room for 68 days. Moisture concentrations of the corn hybrids ranged from approximately 60% to 72% and were lower ($P \leq 0.05$) in late-maturing hybrids relative to early maturing hybrids. Differences in silage quality among hybrids were mainly associated with moisture concentration at ensiling. Silage pH, and concentrations of lactic acid, acetic acid and total acids were greater ($P \leq 0.05$) in hybrids ensiled at 72% moisture relative to 60% moisture. Regression analysis indicated that moisture concentration at ensiling was a significant predictor ($P \leq 0.05$) of silage pH, lactic acid, acetic acid and total acids, explaining 84%, 55%, 65% and 52%, respectively, of the variation in these silage quality attributes. Reducing variation in moisture concentration by selecting silage corn hybrids with a narrower range in relative maturity would lead to more uniform silage quality.

Introduction

Corn silage is an important forage source for North Dakota's 1.95 million beef cattle. Annually, 2.45 million tons of corn were harvested for corn silage from 151,000 acres in North Dakota during the last five years (U.S. Department of Agriculture/National Agricultural Statistics Service, 2016-2020).

The popularity of corn silage among North Dakota producers is the result of the high dry matter and nutrient yield of corn silage, as well as ease of incorporation into total mixed rations for beef cattle. Unlike hay, large amounts of corn can be conserved rapidly as silage in a short time period, thus reducing the risk of damage from inclement weather.

Seed companies are developing new silage corn hybrids that are better adapted to the climate of northern and western North Dakota (Dahlen and Meehan, 2018). Early and late-maturing silage corn hybrids are available in North Dakota and hybrid selection will depend on producer preference. Selection of hybrids with varying maturity may widen the harvest window but can cause considerable variation in moisture concentration at harvest (Coulter, 2018).

Forage moisture concentration at ensiling has substantial effects on silage fermentation (Muck and Kung, 2007). High moisture concentration increases effluent losses and clostridial fermentation, reducing the feeding value of the silage. Low moisture concentration at ensiling predisposes a silage to aerobic microbial spoilage and heating (Muck and Kung, 2007).

The moisture concentration of silage samples collected across North Dakota, ranging from 28% to 80% (Dahlen and Meehan, 2018), suggests that the quality of silages produced in North Dakota is highly variable. This study was conducted to evaluate nutrient concentration and quality of new silage corn hybrids ensiled at varying maturities and moisture concentrations.

Experimental Procedures

Silage corn hybrids were planted in experimental plots on May 28, 2020, using a John Deere 1700 Max-Emerge Plus planter. Experimental plots were on Wabek-Appam soils classified as gravelly sandy loam

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soils on 6% to 9% slopes. Plots were fertilized with 44.8 kilograms per hectare (kg/ha) of phosphorus (P), 22.4 kg/ha potassium (K) and 224 kg/ha urea following North Dakota Soil Testing Laboratory recommendations after soil tests. The plots were harvested on Sept. 7, 2020, using a two-row Gehl corn chopper that deposited forage directly into a Knight mixer/feed wagon equipped with a digital scale.

Early and late-maturing silage corn hybrids were evaluated for nutrient concentration and quality. The selected hybrids were Mycogen 0526AM, Mycogen 1247AMXT, Mycogen TMF94L37, Dairyland 3099RA, Dairyland 3211, Croplan CP3899VT2P, Croplan CP4100SV2P, Croplan CP5000SAS3122, NK E105, Pioneer P0157AMXT, Pioneer P9608Q and Legacy L5467. The hybrids ranged in relative maturity from 94 to 111 days.

Approximately 500 grams (g) of forage samples from three replicates of each hybrid were ensiled in 30- by 22-centimeter (cm) polyethylene bags (Sunbeam Products; foodsaver.com). The bags were vacuum-sealed using a commercial sealer (Maxvac 250, LEM Products, West Chester, Ohio, lemproducts.com) and stored at 21 C in a temperature-controlled room for 68 days. The silage corn hybrids were analyzed for silage quality at Dairyland laboratories (Dairyland Laboratories Inc., St. Cloud, Minn., lab). Starch content was determined in corn samples prior to ensilage using an enzymatic-colorimetric Method. Silage pH value was determined using a standard pH electrode (Standard Methods for the Examination of Water and Wastewater. 1995). Lactic acid, acetic acid, propionic acid, and butyric acid were analyzed by High Performance Liquid Chromatography.

Results and Discussion

The moisture concentration at the time of ensilaging was greater ($P \le 0.05$) in late-maturing hybrids (3211, CP4100SV2P, CP5000SAS3122 and E105) relative to early maturing hybrids (0526AM, P9608Q and P0157AMXT). We found no difference in crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), calcium (Ca), P, magnesium (Mg) and sulfur (S) among hybrids (results not shown).

The starch concentration ranged from 14.7% to 34.5% among hybrids and was greater ($P \le 0.05$) in early maturing hybrids relative to late-maturing hybrids. The silage pH was lower ($P \le 0.05$) in late-maturing hybrids relative to early maturing hybrids (Table 1). Concentrations of lactic and acetic acid were greater ($P \le 0.05$) in late-maturing hybrids relative to early maturing hybrids.

The ethanol concentration was low in all silages (Table 1). Ammonia as a percentage of CP was low, ranging from 3.7% to 5.2%, and did not differ among hybrids (Table 1).

Differences in silage quality among hybrids largely resulted from differences in moisture concentration at the time of ensiling. Forage moisture concentration at ensiling has substantial effects on silage fermentation (Muck and Kung, 2007). Silage pH, and concentrations of

Table 1. Silage acidity (pH) and concentration of organic acids, ethanol and ammonia in silage corn hybrids ensiled at different maturities.

	Corn hybrid[1]													
	26AM	AMXT	99RA	3211	VT2P	SV2P	3122	E105	5467	7AMX	608Q	4L37	SE	P
pH	3.91^{ab}	3.86^{bc}	3.87^{abc}	3.71f	3.84^{bcd}	3.77^{def}	3.75^{ef}	3.75^{ef}	3.82^{cde}	3.89^{abc}	3.89^{abc}	3.94^{a}	0.03	<0.001
Lactic acid, %	6.02^{cde}	5.76^{cde}	6.34^{abcde}	7.72^{ab}	6.42^{abcde}	6.72^{abcd}	7.95^{a}	7.25^{abc}	5.46^{de}	4.74^{e}	5.10^{de}	6.23^{bcde}	0.72	0.003
Acetic acid, %	1.46^{bcd}	1.53^{abcd}	1.64^{abcd}	2.18^{a}	1.83^{abc}	1.71^{abcd}	2.02^{ab}	2.05^{ab}	1.43^{bcd}	1.17^{cd}	1.10^{d}	1.42^{bcd}	0.29	0.016
Butyric acid	ND[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Propionic acid	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Total acids	7.47^{bcd}	7.28^{bcd}	7.64^{bcd}	10.30^{a}	8.25^{abc}	8.43^{ab}	9.97^{a}	9.96^{a}	6.88^{bcd}	5.92^{d}	6.20^{bcd}	7.65^{bcd}	0.91	<0.001
Lactic:Acetic[3]	4.13	3.83	4.16	3.67	3.71	3.74	3.57	3.37	4.06	4.04	4.64	4.45	0.39	0.111
Lactic, %total	80.5	79.2	80.6	78.7	78.7	78.8	77.3	77.1	79.9	80.1	82.2	81.5	1.6	0.102
Ethanol, %	0.48^{ab}	$0.44a^{ab}$	0.44^{ab}	0.48^{ab}	0.42^{ab}	0.33^{b}	0.39^{b}	0.32^{b}	0.33^{b}	0.41^{ab}	0.48^{ab}	0.57^{a}	0.07	0.035
Ammonia, %CP	4.46	4.25	4.55	5.18	4.83	4.80	4.95	4.58	4.51	4.60	3.72	4.66	0.45	0.279

[1]26AM = Mycogen 0526AM; AMXT = Mycogen 1247AMXT; 99RA = Dairyland 3099RA; 3211 = Dairyland 3211; VT2P = Croplan CP3899VT2P; SV2P = Croplan CP4100SV2P; 3122 = Croplan CP5000SAS3122; E105 = NK E105; 5467 = Legacy L5467; 7AMX = Pioneer P0157AMXT; 608Q = Pioneer P9608Q; 4L37 = Mycogen TMF94L37.
[2]Not detected.
[3]Lactic acid-to-acetic acid ratio.
Means within a row with different superscripts differ ($P \le 0.05$).

lactic acid, acetic acid and total acids were greater ($P \leq 0.05$) in hybrids ensiled at 72% moisture (Table 2).

Regression analysis indicated that moisture concentration at ensiling was a significant predictor of silage pH, lactic acid, acetic acid and total acids explaining 84%, 55%, 65% and 52%, respectively, of the variance in these attributes (Figure 1). Typical corn silage will have a pH between 3.7 and 4.2, and contain 4% to 7% lactic acid, 1% to 3% acetic acid, 1% to 3% ethanol, 5% to 7% ammonia-N and no butyric acid (Kung and Shaver 2001).

Based on criteria for typical corn silage, ensiling corn hybrids at moisture concentrations ranging from 60% to 72% generally produced good-quality silages. Reducing variation in moisture concentration by selecting silage corn hybrids with a narrow range in relative maturity would lead to more uniform silage quality.

Acknowledgments

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Table 2. Effect of moisture concentration at ensiling on silage pH, and concentration of organic acids, ethanol and ammonia.

	Moisture content at ensiling, %							
	60	62	64	66	69	72	SE	P
pH	3.90^{ab}	3.92^{a}	3.87^{bc}	3.83^{c}	3.76^{d}	3.73^{d}	0.022	<0.001
Lactic acid, %	5.56^{c}	5.49^{c}	6.04^{bc}	5.94^{bc}	6.98^{ab}	7.83^{a}	0.546	0.001
Acetic acid, %	1.28^{c}	1.30^{c}	1.58^{bc}	1.63^{bc}	1.88^{ab}	2.10^{a}	0.204	0.002
Butyric acid	ND[1]	ND	ND	ND	ND	ND		
Propionic acid	ND	ND	ND	ND	ND	ND		
Total acids	6.83^{b}	6.78^{b}	7.46^{b}	7.57^{b}	9.20^{a}	10.13^{a}	0.695	<0.001
Lactic: Acetic[2]	4.39^{a}	4.25^{a}	4.00^{ab}	3.88^{ab}	3.56^{b}	3.62^{b}	0.273	0.027
Lactic, %total	81.4^{a}	80.8^{a}	79.9^{ab}	79.3^{ab}	77.9^{b}	78.0^{b}	1.13	0.019
Ethanol, %	0.48^{a}	0.49^{a}	0.44^{a}	0.38^{ab}	0.33^{b}	0.42^{ab}	0.047	0.020
Ammonia, %CP	4.09	4.62	4.40	4.67	4.69	5.07	0.324	0.080

[1]Not detected.
[2]Lactic acid-to-acetic acid ratio.
Means within a row with different superscripts differ ($P \leq 0.05$).

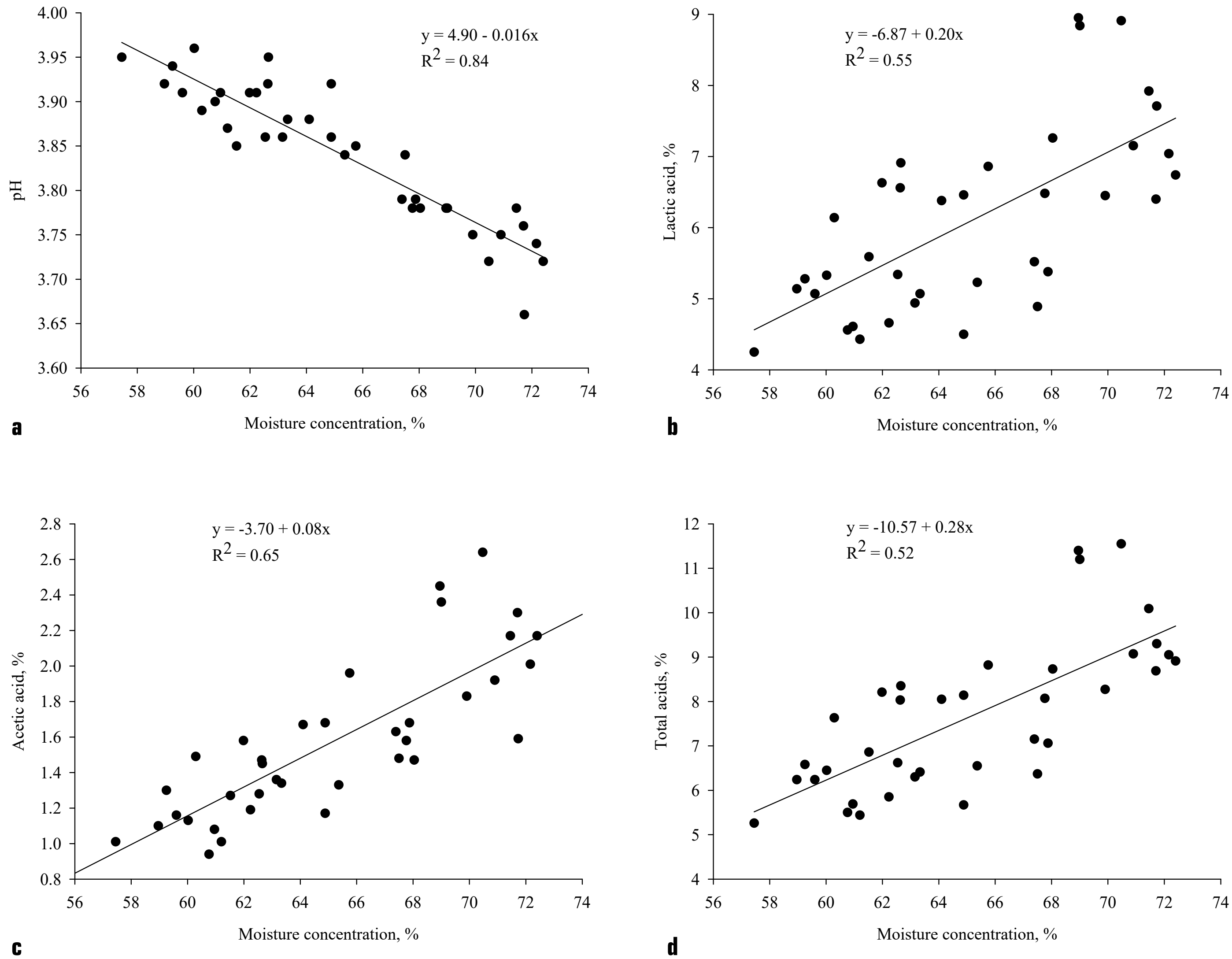

Figure 1. Effect of moisture concentration at ensiling on a) silage pH, and concentration of b) lactic acid, c) acetic acid and d) total acids.

Vitamin and mineral supplementation and rate of gain in beef heifers: Effects on concentration of trace minerals in maternal and fetal liver at day 83 of gestation

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The objective of this study was to evaluate the effects of feeding vitamin and mineral supplement and two different rates of gain during the first 83 days of pregnancy on trace mineral concentrations in maternal and fetal liver. Our results show that providing a vitamin and mineral supplement resulted in increased concentrations of selenium (Se), copper (Cu), manganese (Mn) and cobalt (Co) in fetal liver. Increased trace mineral stores in the liver may be beneficial for offspring health and productive performance.

Summary

The objective of this study was to evaluate the effects of feeding vitamin and mineral (VTM) supplement and two different rates of gain during the first 83 days of pregnancy on trace mineral concentrations in maternal and fetal liver. Thirty-five crossbred Angus heifers (initial body weight [BW] = 792.6 ± 15.7 pounds [lb.]) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplement (VTM or NoVTM) and rate of gain (GAIN; low gain [LG], 0.62 pounds per day [lb./d], vs. moderate gain [MG], 1.74 lb./d). The VTM treatment (113 grams [g]/heifer/day) was initiated at least 71 days before artificial insemination (AI). At breeding, heifers were maintained on their respective diets (target gain of 0.62 lb./d) or fed a starch-based protein/energy supplement (target gain of 1.74 lb./d). Heifers were ovariohysterectomized on day 83 of gestation and samples of maternal and fetal liver were collected. Samples then were analyzed for concentrations of Se, Mn, Cu, Co, molybdenum (Mo) and zinc (Zn). In maternal liver, a VTM × GAIN was observed for Se ($P = 0.02$) and Mn ($P = 0.03$); Se concentrations were greater for VTM-LG than all other treatments, while Mn concentrations were greater for VTM-MG than VTM-LG heifers. Further, maternal liver from VTM had increased concentrations of Cu ($P < 0.01$) and Co ($P = 0.04$), whereas GAIN affected concentrations of Mo, with greater concentrations ($P \leq 0.02$) in MG heifers. Greater concentrations of Se ($P < 0.01$), Cu ($P = 0.01$), Mn ($P = 0.04$) and Co ($P = 0.01$) were observed in fetal liver from VTM than NoVTM, while Mo ($P \leq 0.04$) and Co ($P < 0.01$) in fetal liver were greater in LG than MG. In conclusion, concentrations of Se, Cu, Mn and Co were greater in fetal liver from VTM dams, while greater concentrations of Mo were observed in the liver of fetuses from LG dams. Concentrations of Zn were not affected by any of the nutritional strategies evaluated. These data provide insights into how nutritional management of beef heifers affect fetal liver stores of trace minerals, which may be beneficial for offspring health and productive performance.

Introduction

The first trimester of gestation is a critical period for fetal development, when the placenta and all vital organs are developed. Many producers don't realize that at that stage, not only the dam, but also the fetus, require proper trace mineral nutrition.

However, several biological processes, such as carbohydrate, protein and lipid metabolism, hormone and DNA synthesis are dependent on trace minerals (Van Emon et al., 2020). Further, the fetus is completely dependent on the dam for trace mineral supply; thus, an inadequate maternal trace mineral consumption can compromise reproduction and negatively affect embryonic and fetal development (Hostetler et al., 2003), which can have long-term consequences on offspring health and performance.

Therefore, developing studies evaluating how maternal nutritional strategies can affect the supply of trace minerals to the fetus is important. The current experiment

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characterized a research model we developed to evaluate the effect of managerial inputs on maternal and fetal trace mineral concentration. The primary aim of this study was to test the hypothesis that vitamin and mineral supplementation and rate of gain during the first trimester of gestation influences the concentrations of trace minerals in maternal and fetal liver.

Experimental Procedures

All procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Thirty-five crossbred Angus heifers (initial BW = 792.6 ± 15.7 lb.) were assigned randomly to one of four treatments in a 2 × 2 factorial arrangement with main effects of vitamin and mineral supplementation (VTM or NoVTM) and rate of gain (GAIN; low gain [LG] 0.62 lb./d or moderate gain [MG] 1.74 lb./d). Briefly, the VTM supplement was initiated at least 71 days before artificial insemination.

At breeding, heifers were maintained on their respective diets (LG) or fed a starch-based protein/energy supplement (MG). This resulted in the following treatment combinations: 1) No vitamin and mineral supplement, low gain (NoVTM-LG; n = 9); 2) No vitamin and mineral supplement, moderate gain (NoVTM-MG; n = 9); 3) Vitamin and mineral supplement, low gain (VTM-LG; n = 9); 4) Vitamin and mineral supplement, moderate gain (VTM-MG; n = 8). Heifers were fed individually using Calan gates, and supplements were top dressed over the total mixed ratio (Table 1).

Heifers were ovariohysterectomized on day 83 ± 0.27 of gestation. Liver biopsies were obtained from all heifers at surgery day. Following ovariohysterectomy, fetuses were harvested and dissected, and samples of fetal liver were collected. Samples were placed in 2 milliliter microtubes and snap frozen on dry ice and stored at minus 80 C for subsequent trace mineral analysis.

Concentrations of Se, Mn, Cu, Co, Mo and Zn were determined via inductively coupled plasma mass spectrometry at the Veterinary Diagnostic Laboratory at Michigan State University. Data were analyzed using the MIXED procedures of SAS for effects of VTM, GAIN and a VTM × rate of gain interaction. Differences were considered significant at a P- value ≤ 0.05.

Results and Discussion

In maternal liver (Table 2), a VTM × GAIN was observed for Se (P = 0.02) and Mn (P = 0.03); Se concentrations were greater for VTM-LG than all other treatments, while Mn concentrations were greater for VTM-MG than VTM-LG heifers. Further, maternal liver from VTM had increased concentrations of Cu (P < 0.01) and Co (P = 0.04), whereas GAIN affected concentrations of Mo, with greater concentrations (P ≤ 0.02) in MG heifers.

Table 1. Nutrient composition of total mixed ration and supplements provided to beef heifers during the first trimester of gestation.

Chemical Composition	Total Mixed Ration[1]	Supplements: NoVTM[2]	Supplements: VTM[3]	Supplements: Starch-based protein/ energy[4]
Dry matter, %	53.0	86.6	89.6	87.7
Ash, % DM	11.5	5.3	25.1	2.4
Crude protein, % DM	9.9	15.6	14.8	17.5
Neutral detergent fiber, % DM	65.9	41.9	27.6	19.4
Ether extract, % DM	1.5	-	-	9.1
Nonfiber carbohydrates, % DM	11.1	37.2	32.5	51.6
Mineral Content				
Calcium, g/kg DM	5.74	2.47	50.62	0.30
Phosphorus, g/kg DM	2.05	8.94	22.82	4.59
Sodium, g/kg DM	0.26	0.12	19.44	0.24
Magnesium, g/kg DM	2.83	4.47	5.20	1.96
Potassium, g/kg DM	15.81	14.22	13.15	6.05
Sulfur, g/kg DM	2.25	2.41	4.84	2.57
Manganese, mg/kg DM	121.2	103.9	953.4	26.0
Cobalt, mg/kg DM	0.36	0.14	3.38	0.05
Copper, mg/kg DM	4.8	13.7	285.8	3.6
Selenium, mg/kg DM	0.3	0.4	7.0	0.3
Zinc, mg/kg DM	28.4	130.2	1051.8	35.0

[1]Proportion of ingredients: prairie grass hay (55%), corn silage (38%) and dried distillers grains plus solubles (7%).

[2]NoVTM: No vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day with no added vitamin and mineral supplement.

[3]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day (consisting of 113 grams (g) of a vitamin and mineral supplement [Purina Wind & Rain Storm All-Season 7.5 Complete, Land O'Lakes Inc., Arden Hills, Minn.] and 337 g of a carrier).

[4]An energy/protein supplement formulated with a blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea; targeting gain of 1.74 lb./d for moderate gain and 0.62 lb./d for low-gain heifers.

In fetal liver (Table 3), greater concentrations of Se ($P < 0.01$), Cu ($P = 0.01$), Mn ($P = 0.04$) and Co ($P = 0.01$) were observed in fetal liver from VTM than NoVTM dams, while Mo ($P \leq 0.04$) and Co ($P < 0.01$) concentrations were greater in fetal liver from LG than MG dams.

We would expect greater concentrations of all trace minerals in maternal and fetal liver in response to vitamin and mineral supplementation. However, that was not the case for two of the six trace minerals evaluated, Mo and Zn, whose concentrations were not affected by VTM supplementation.

Interestingly, heifers with moderate rates of gain had greater liver concentrations of Mo than LG heifers, but the opposite relationship was observed in fetal liver. We may speculate that the protein/energy

Table 2. Concentrations of trace minerals in the liver of beef heifers at day 83 of gestation as influenced by vitamin and mineral (VTM) supplementation and rate of gain (GAIN; low rate, 0.45 kg/d [LG] or moderate rate, 0.79 kg/d [MG]) in early gestation.

Mineral concentration, ug/g dry	NoVTM[1]		VTM[2]			P-value		
	LG	MG[3]	LG	MG[3]	SEM[4]	VTM	GAIN	VTM × GAIN
Selenium	1.64[c]	1.54[c]	2.87[a]	2.26[b]	0.11	<0.01	<0.01	0.02
Copper	39.35	27.35	196.27	184.21	14.64	<0.01	0.39	0.99
Manganese	9.94[ab]	9.86[ab]	8.46[b]	10.85[a]	0.58	0.66	0.04	0.03
Cobalt	0.20	0.19	0.24	0.21	0.01	0.04	0.26	0.41
Molybdenum	3.58	3.85	3.39	3.95	0.17	0.76	0.02	0.36
Zinc	119.49	120.73	121.95	123.93	6.04	0.63	0.78	0.95

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at a 0.99 lb./heifer/day with no added vitamin and mineral supplement.
[2]VTM: Vitamin mineral supplement was a pelleted product fed at a 0.99 lb./heifer/day (consisting of 113 g of a mineral and vitamin supplement, formulated to deliver similar levels of vitamins and minerals that were fed pre-breeding, and 337 g of a carrier).
[3]Heifers fed a pelleted blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea, targeting a gain of 1.74 lb./d.
[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).
[ab]means without a common superscript differ ($P \leq 0.05$).

Table 3. Concentrations of trace minerals in fetal liver at day 83 of gestation as influenced by maternal vitamin and mineral (VTM) supplementation and rate of gain (GAIN; low rate, 0.45 kg/d [LG] or moderate rate, 0.79 kg/d [MG]) in early gestation.

Mineral concentration, ug/g dry	NoVTM[1]		VTM[2]			P-value		
	LG	MG[3]	LG	MG[3]	SEM[4]	VTM	GAIN	VTM × GAIN
Selenium	4.23	4.25	6.25	6.39	0.46	<0.01	0.86	0.89
Copper	246.01	277.84	298.21	348.91	22.75	0.01	0.08	0.68
Manganese	5.09	4.78	5.19	6.03	0.32	0.04	0.39	0.07
Cobalt	0.07	0.05	0.09	0.06	0.01	0.01	<0.01	0.27
Molybdenum	0.37	0.33	0.36	0.33	0.02	0.79	0.04	0.81
Zinc	440.61	448.24	541.2	563.76	85.35	0.21	0.85	0.93

[1]NoVTM: No vitamin and mineral supplement was a pelleted product fed at 0.99 lb./heifer/day with no added vitamin and mineral supplement.
[2]VTM: Vitamin mineral supplement was a pelleted product fed at 0.99 lb./heifer/day (consisting of 113 g of a mineral and vitamin supplement, formulated to deliver similar levels of vitamins and minerals that were fed pre-breeding, and 337 g of a carrier).
[3]Heifers fed a pelleted blend of ground corn, dried distillers grains plus solubles, wheat midds, fish oil and urea, targeting a gain of 1.74 lb./d.
[4]NoVTM-LG (n = 9); NoVTM-MG (n = 9); VTM-LG (n = 9); VTM-MG (n = 8).

supplement provided to MG heifers already was providing enough minerals to meet fetal requirements, therefore unsupplemented heifers (LG) had to mobilize more nutrients to the developing fetus to ensure an adequate supply and consequently liver storage.

Fetal liver stores of trace minerals are important for the neonate because bovine milk is poor in essential trace minerals (Abdelrahman and Kincaid, 1993). Additionally, an adequate trace mineral reserve is crucial in early life to maintaining health status (Van Emon et al., 2020).

In conclusion, concentrations of Se, Cu, Mn and Co were greater in fetal liver from VTM dams, while greater concentrations of Mo were observed in the liver of fetuses from LG dams. Concentrations of Zn were not affected by any of the nutritional strategies evaluated. These data provide insights into how nutritional management of beef heifers affect fetal liver stores of trace minerals, which may be beneficial for offspring health and productive performance.

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Effects of feeding a vitamin and mineral supplement to cow-calf pairs grazing native range

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The objectives of this study were to evaluate the influence of feeding a vitamin and mineral (VTM) supplement to pregnant cows and suckling calves during the summer grazing period on native rangeland. Although performance measures in cows or calves were not affected, concentrations of liver mineral were enhanced in cows and calves that had access to free-choice mineral while grazing summer pastures.

Summary

Our objectives were to evaluate how providing free-choice vitamin and mineral (VTM) supplements to cow-calf pairs during the summer grazing period on native range affects cow and calf performance and liver mineral concentrations. During a two-year period, Angus-based crossbred cow-calf pairs (n = 727; n = 381 in year 1, n = 346 in year 2) from the Central Grasslands Research Extension Center (Streeter, N.D.) were assigned to pastures (16 in year 1, 14 in year 2), which then were assigned to receive a free-choice mineral supplement (**Mineral**) or no mineral supplement (**NoMineral**). Prior to treatment assignments, all cow-calf pairs received a common diet as a total mixed ration including a mineral supplement for 120 days before pasture turnout. The grazing periods for year 1 and year 2 were 158 and 156 days, respectively, and treatments began at pasture turnout and concluded at pasture removal. Cows were bred on pasture using artificial insemination followed by natural service cleanup bulls for a 70- to 80-day breeding season. Weights were collected from cows and calves at pasture turnout and removal and liver biopsies were taken from a subset of cows and calves. Additionally, birth weights and calving distribution were evaluated. Cow and calf weights and weight change during the grazing period were not impacted ($P \geq 0.47$) by access to VTM supplement. Furthermore, the pregnancy rate and subsequent birth weight and calving distribution were not affected ($P \geq 0.36$) by treatment. Liver concentrations of selenium, copper and cobalt were greater ($P \leq 0.002$) at pasture removal and weaning for cows and suckling calves that had access to VTM. Although VTM supplementation enhanced concentrations of key minerals in the liver of cows and calves, performance was not impacted.

Introduction

Successful cow-calf herds rely on reproductive efficiency to maintain profitability; thus, maintaining adequate maternal nutritional status, including vitamin and mineral nutrition, is essential to optimal growth, development and programming of the fetus (Kegley et al., 2016). However, management strategies vary widely across beef herds, with innumerable strategies of offering vitamin and mineral supplementation and intensities of supplementation programs being implemented by producers.

Vitamins and minerals are transferred across the placenta to the growing fetus during gestation; however, the long-term implications of the mineral status established at birth in the neonate have yet to be elucidated (Hidiroglou, 1980; Hostetler et al., 2003; Menezes et al., 2021). Therefore, this study evaluated influences of vitamin and mineral supplementation on growth performance and mineral status of the dam and suckling calves throughout the grazing period, reproductive success in the dam, and birthweight and calving distribution of the calf crop.

Experimental Procedures

Animals, Housing and Diet

During a two-year period, 727 Angus-based crossbred cow-calf pairs (n = 381 in year 1, n = 346 in year 2) were used at the Central Grasslands Research Extension Center to evaluate the influence of providing free-choice VTM supplements during the grazing season on cow-calf herd performance. Prior to treatment assignments, all cows and calves were fed a common diet as a total mixed ration including a mineral supplement for 120 days before pasture turnout.

Cow-calf pairs were blocked by cow age, then randomly assigned to one of 16 pastures in year 1 and one of 14 pastures in year 2. Pastures were assigned randomly to one of two treatments: 1) free choice VTM

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supplement was available in the pasture (**Mineral**) or 2) no mineral supplement was available in the pasture (**NoMineral**). The grazing period for years 1 and 2 were 158 and 156 days, respectively, and treatments began at pasture turnout and concluded at the time the pairs were removed from pasture.

All pastures were stocked at the same stocking rate to achieve 40% to 50% degree of disappearance. The vitamin and mineral supplement was offered in free-choice mineral feeders placed in each pasture and consumption was monitored. Mineral feeders were accessible for all cows and calves on pastures receiving the treatment.

The vitamin and mineral supplement in year 1 was Stockmen's Supply Repromune MIN YC (Stockmen's Nutrition, West Fargo, N.D.) and in year 2, the supplement offered was Payback Research 12-6+ (CHS Nutrition, Sioux Falls, S.D.). Cows were synchronized using a 7-CoSynch artificial insemination (AI) protocol and bred to multiple sires and natural service cleanup bulls were turned out shortly after AI.

Pregnancy status was determined via transrectal ultrasonography at least 40 days after bull removal to determine overall pregnancy rates. Cows remained on pasture with their suckling calf until the end of the grazing season (weaning).

Cow/calf Performance

Calf weights were recorded at birth, pasture turnout and weaning. Consecutive day cow weights were recorded at pasture turnout and removal from pasture. Average two-day weights for turnout and removal were used to calculate performance on pasture. Gain during the grazing period and average daily gain were calculated for cows and calves.

Pregnancy ultrasound data were evaluated to assess overall pregnancy rates. Furthermore, calving records were analyzed to determine calving distribution.

Mineral Status

Liver biopsies were taken at pasture turnout and removal from a subset of 16 cows in year 1 and 42 cows in year 2. In addition, samples were collected from a subset of 47 calves in year 1 and 35 calves in year 2 within a week of weaning.

Samples were collected using a Tru-Cut biopsy trochar (14 g; Becton Dickinson Co., Franklin Lakes, N.J.) using techniques outlined by Engle and Spears (2000) and McCarthy et al., (2019). Samples were analyzed for concentrations of selenium, iron, copper, zinc, molybdenum, manganese and cobalt at the Diagnostic Center for Population and Animal Health at Michigan State University using inductively coupled plasma mass spectrometry.

Statistical Analysis

Mean values for individual cows and calves within a pasture were calculated and used to represent the pasture in the final data set. For concentrations of liver mineral, mean pasture values were calculated for each pasture and used for analysis. Data were analyzed for the effect of VTM treatment (Mineral or NoMineral) using the GLM procedure of SAS with pasture as the experimental unit. Differences were considered significant at a P-value ≤ 0.05.

Results and Discussion

Cow weight change and pregnancy attainment were not influenced by VTM supplementation on pasture (P = 0.99 and P = 0.36, respectively; Table 1). Pregnancy rates in suckled beef cows between both years were not different between treatments, with mineral supplemented cows at 95.3% and nonsupplemented cows at 96.4% (P = 0.36; Table 1). Overall performance and pregnancy success were adequate for cows in both treatment groups.

Weaning weights of suckling calves were also not different (P = 0.47) between treatments, with Mineral calves weaned at an average of 605 pounds and NoMineral calves weaned at an average of 595 pounds (Table 2). Additionally, average daily gain (ADG) was not different between treatments (P = 0.325).

The birth weight of the calf conceived during the grazing season did not differ (P = 0.447; Table 2) between treatments, with Mineral calves averaging 87 pounds and NoMineral calves averaging 85 pounds at birth. The date of birth in the calving season was also not impacted by treatment (P = 0.72).

The *in-utero* environment experienced by calves during gestation is a product of the dam's environ-

Table 1. Effect of mineral supplement availability on performance of suckled beef cows.

	Treatment[1]			
Item	**No Mineral**	**Mineral**	**SE**	***P*-Value**
Turnout wt, lbs.	1,325.0	1,330.5	30.6	0.90
Pasture removal wt, lbs.	1,384.5	1,390.3	30.4	0.89
Cow wt change, lbs.	58.0	58.0	7.41	0.99
Pregnancy rate, lbs.	96.4	95.3	0.82	0.36

[1]Treatments were: **No Mineral**–Cows were grazing pastures with no access to a mineral supplement or **Mineral**–Cows were grazing pastures with access to a mineral supplement.

ment. Nutrients consumed, climactic conditions and stress experienced by dams all can impact the developing fetus.

Vitamins and minerals can serve several key roles in growth and development in the body of the gestating dam as well as the fetus, including structural, physiological, catalytic and regulatory functions, which contribute to effects on hormone production, enzyme activity, tissue growth, oxygen transport and energy production (Menezes et al., 2021). Evaluation of calf crops conceived by dams that received different VTM treatments during the grazing period (the first trimester of gestation) should be continued at later post-natal and post-pubertal time points.

Liver selenium, copper and cobalt concentrations were greater ($P \leq 0.002$) in Mineral cows at pasture removal compared with NoMineral cows (Table 3). Additionally, the change in concentrations of liver selenium, copper and cobalt from pasture turnout to pasture removal was greater ($P \leq 0.003$) for Mineral cows than NoMineral cows. At pasture removal, concentrations of iron, zinc, molybdenum and manganese in cows were not influenced ($P \geq 0.222$) by treatment.

At weaning, concentrations of selenium, copper and cobalt were greater ($P \leq 0.001$) for calves managed on Mineral pastures compared with calves managed on NoMineral pastures (Table 4). Concentrations of iron, zinc, molybdenum and manganese in calves were not influenced ($P \geq 0.17$) by treatment at weaning.

In the current experiment, providing a mineral supplement to suckled cows did not influence performance of the cows, suckling calves or gestating calves (Tables 1 and 2). However, data provided in Tables 3 and 4 indicate that liver

Table 2. Effect of mineral supplement availability on performance of calves.

	Treatment[1]			
Item	**No Mineral**	**Mineral**	**SE**	***P*-Value**
Suckling calf				
Turnout wt., lbs.	185.4	183.0	2.92	0.56
Weaning wt. lbs.	595.0	604.8	9.55	0.47
Calf gain, lbs.2	410.3	421.9	8.14	0.32
Calf ADG, lbs.	2.61	2.69	0.05	0.32
Gestating calf				
Day of calving	17.75	18.22	0.92	0.72
Birth wt, lbs.	85.26	86.62	1.25	0.45

[1]Treatments were: **No Mineral**–calves were grazing pastures where they (along with their dams) had no access to a mineral supplement or **Mineral**–calves were grazing pastures where they (along with their dams) had access to a mineral supplement.

Table 3. Effects of mineral supplement availability on liver mineral concentrations in suckled cows grazing native range[1]; combined averages of years 1 and 2.

			Treatment[2]			
	Sample		**No Mineral**	**Mineral**	**SE**	***P*-Value**
			---------µg/g---------			
Selenium, Se	Turnout		1.87	1.78	0.066	0.33
	Removal		2.22	2.87	0.138	0.002
		CHG[3]	0.34	1.08	0.155	0.002
Iron, Fe	Turnout		276.1	263.0	18.46	0.61
	Removal		265.1	252.0	15.73	0.55
		CHG	-11.05	-11.03	16.40	0.99
Copper, Cu	Turnout		204.8	183.1	12.97	0.23
	Removal		183.0	302.4	19.89	<0.001
		CHG	-21.84	119.28	20.40	<0.001
Zinc, Zn	Turnout		139.8	141.1	8.66	0.91
	Removal		149.0	172.2	13.5	0.22
		CHG	9.29	31.09	14.49	0.28
Molybdenum, Mo	Turnout		3.78	3.82	0.121	0.82
	Removal		4.30	4.20	0.092	0.46
		CHG	0.514	0.381	0.127	0.45
Manganese, Mn	Turnout		11.13	11.44	0.326	0.52
	Removal		11.16	11.44	0.316	0.52
		CHG	0.035	0.003	0.344	0.95
Cobalt, Co	Turnout		0.239	0.233	0.0109	0.70
	Removal		0.163	0.300	0.0278	0.001
		CHG	-0.076	0.067	0.0319	0.003

[1]For this analysis, mineral concentration values were averaged between years 1 and 2.
[2]Treatments were: **No Mineral**–Cows were grazing pastures with no access to a mineral supplement or **Mineral**–Cows were grazing pastures with access to a mineral supplement.
[3]Change in concentration: reflects the concentration at pasture removal minus the value from pasture turnout.

Table 4. Effects of mineral supplement availability on liver mineral concentrations in suckling calves grazing native range.

	Treatment[1]			
Item, μg/g	No Mineral	Mineral	SE	*P*-Value
Se	1.62	1.93	0.063	0.001
Fe	203.8	179.3	14.93	0.25
Cu	48.4	103.3	6.88	<0.001
Zn	168.3	169.0	6.50	0.94
Mo	3.45	3.19	0.130	0.17
Mn	8.78	9.06	0.277	0.47
Co	0.114	0.172	0.009	<0.001

[1]Treatments were: **No Mineral**–Calves were grazing pastures with no access to mineral supplement or **Mineral**–Calves were grazing pastures with access to mineral supplement. Payback Research 12-6+, CHS Nutrition, Sioux Falls, S.D. Values from 35 calves used to determine pasture averages.

mineral concentrations were enhanced in cows and calves provided with a mineral supplement during the grazing period.

Research by Ahola et al. (2004) supported similar findings, with greater copper liver mineral concentrations in supplemented dams compared with nonsupplemented dams for two years, but performance data varied slightly as a result of mineral supplementation. In the study by Aloha et al. (2004), overall 60-day pregnancy rates tended to be higher for supplemented cows compared with nonsupplemented cows, an effect that was not observed in the current study. Management factors that impact pregnancy attainment or calf growth warrant careful investigation because of their intricate relationship with herd profitability.

Weaning data for calves conceived and gestated in year 2 of this experiment will be collected in the fall of 2021, which will complete a dataset used to evaluate the impact of early gestation mineral supplementation on subsequent offspring performance. When evaluating overall implications of pasture-based mineral supplementation programs, additional evaluations, including assessing immune status of the suckling calves, and post-weaning health implications should be considered. Strategies that enhance immunity and reduce susceptibility to disease in newly weaned calves would be a great benefit to backgrounding and feedlot operations.

The effects on the gestating calf receiving the mineral treatment in utero also should be evaluated further in terms of the potential to program the growing fetus to utilize micronutrients more efficiently. Furthermore, vitamin and mineral deficiencies during stressful events in a calf's life, such as weaning and transport, can become more apparent (Kegley et al., 2016). Decreasing the incidence of morbidity and maintaining calf health may be an outlet to increasing overall calf performance, but further research is necessary to determine the impact vitamin and mineral supplementation may have in scenarios where calf immune status is challenged.

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Effect of rate of gain during early gestation on colostrum and milk composition in beef heifers

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The objectives of this study were to evaluate the impact of feeding an energy/protein supplement to replacement heifers to achieve a moderate rate of gain during the first trimester of gestation (84 days) on composition of colostrum and milk and milk production. Developing heifers to a moderate rate of gain decreased the somatic cell count in colostrum and increased the percent of protein in milk; however, no effects were observed on milk production measured via the weigh-suckle-weigh procedure in this study.

Summary

We hypothesized that rate of gain during the first 84 days of gestation would affect composition of colostrum and milk, and increase milk production in moderate-gain heifers. At breeding, 45 Angus-based heifers received either a basal total mixed ration allowing 0.63 pounds per day (lb/d) gain (low gain [**LG**], n = 23) or basal diet plus starch-based supplement allowing 1.75 lb/d gain (moderate gain [**MG**], n = 22) for 84 days. Heifers then were managed on a common diet until parturition. Colostrum samples (50 milliliters [mL]) were collected before first suckling. Milk samples (50 mL) were collected six hours after calf removal on days 62 ± 10 and 103 ± 10 postpartum. Samples were collected by stripping each teat 15 to 20 times after discarding the first five strips. At day 103, sampling techniques were compared by collecting a second sample after 1 mL oxytocin administration and 90 seconds lag time. The colostrum somatic cell count (**SCC**) was greater ($P = 0.05$) in LG (6,949 ± 739 cells × 10^3/mL) than MG (4,776 ± 796 cells × 10^3/mL). In milk, protein and other solids were greater ($P \leq 0.03$) in MG (3.02 ± 0.03 and 6.20 ± 0.02 %, respectively) than LG (2.87 ± 0.03 and 6.14 ± 0.02 %, respectively). On day 103, oxytocin administration and extended lag time after teat stimulation (0.96 ± 0.05 %) increased fat concentration in milk ($P < 0.01$), compared with immediate milk sample collection (0.34 ± 0.05 %). We conclude that nutrition during early gestation had a sustained impact on milk composition, and techniques of oxytocin administration result in greater milk fat content.

Introduction

In cattle, the development of the mammary gland begins during embryonic development, with the majority of its growth occurring during the last trimester of gestation. By parturition, all components of the gland are established in the fetus, including vascular, lymphatic, connective and adipose tissues (Rowson et al., 2012). In the heifer dam, the majority of apparent mammary growth occurs during the last trimester of gestation and is completed at parturition (Rowson et al., 2012).

Therefore, optimal development and growth of the mammary gland during gestation is essential to ensure maximized milk production in future lactations. Additionally, the mammary gland is a key tissue ensuring the transfer of nutrients and immunoglobulins to the neonatal calf (Neville et al., 2010). Because of the importance of a dam's milk production on her calf's weaning weight, optimizing milking potential is crucial.

Milk is produced in the secretory tissue of the alveoli; however, milk's nutritional constituents and consequently, composition, vary depending on place of storage in the udder. In contrast to casein micelles (protein), which are small enough to passively transfer from the alveoli into the cistern, milk fat globules are larger and require active expulsion from the alveoli. Therefore, fat content is greater in the alveoli than in the cistern, whereas protein content is similar across the two storage sites.

Milk letdown is initiated by oxytocin, which is released from the pituitary gland in response to tactile stimulation of the udder, and causes the myoepithelial cells around the alveoli to contract and eject the milk stored there into the duct system and cistern (Bruckmaier and Blum, 1998). However, an approximate one- to two-minute lag period occurs between the release of oxytocin and milk expulsion (Bruckmaier and Blum, 1998).

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Based on the lack of knowledge that we encountered in the literature regarding maternal nutrition during early gestation and its effects on lactation, we aimed to evaluate the impact of low and moderate gain during the first 84 days of gestation on composition of colostrum and milk, and milk production.

Experimental Procedures

All animal procedures were approved by the Institutional Animal Care and Use Committee at North Dakota State University.

Forty-five Angus-based heifers (initial body weight [**BW**] = 818.2 ± 8.7 pounds) were estrus synchronized using a Select Synch plus CIDR protocol and bred via artificial insemination to female sexed semen from a single sire. At breeding, heifers were blocked by antral follicle count, ranked by BW and assigned to one of two treatments: 1) a basal total mixed ration (TMR; low gain [**LG**] 0.63 lb/d; n = 23) or 2) the basal TMR diet with the addition of a starch-based energy/protein supplement mixed into the diet (moderate gain [**MG**] 1.75 lb/d; n = 25, Table 1).

Heifers were fed individually using the Insentec Feeding System (Hokofarm B.V., Marknesse, The Netherlands). Heifers were weighed on two consecutive days at the beginning and end of the feeding trial, and every 14 days throughout the 84-day period prior to morning feeding, then on days 164, 234 and 262 and at the time of calving, pasture turnout and weaning.

At calving, a 50-mL colostrum sample was collected from each heifer, before calves suckled for the first time. For sample collection, we stripped each teat 15 to 20 times after discarding the first five strips.

At day 62 ± 10 postpartum, we estimated milk production using a 12-hour weigh-suckle-weigh procedure. Briefly, dams and calves were assigned to two groups of 23 and 22 pairs each. At midnight, we separated calves from their dams. At 6 a.m. the next morning, calves were allowed to nurse their dams until satiety (about 30 minutes) to establish similar milking status across the dams.

Then, pairs were separated for two six-hour time periods. After each six-hour window, calves were weighed before and immediately after suckling until satiety (about 30 minutes). The difference between the pre- and post-suckling calf weights was recorded as the estimated milk production of the dam for each of the six-hour time periods.

To estimate 24-hour milk production, milk production for the two six-hour separation periods was added together and multiplied by 2 (Shee et al., 2016). Before allowing the calves to suckle their dams at 6 a.m., we collected a 50-mL milk sample into DHIA vials by stripping each teat 15 to 20 times after discarding the first five strips. Samples were mixed thoroughly and stored at 4 C until further analysis.

At day 103 ± 10 postpartum, the same protocol was used as at day 62 postpartum. Immediately following the collection of the milk sample, we administered oxytocin (1 mL i.m.) to each dam and waited for 90 seconds before collection of another 50-mL milk sample to compare sampling protocols. All samples were shipped to a DHIA milk laboratory (Stearns County DHIA Lab, Sauk Centre, Minn.) within 10 days (colostrum) and five days (milk) after sample collection for analysis of composi-

Table 1. Dietary ingredients and nutrient composition of the total mixed ration fed to beef heifers during the first 84 days of gestation.

	Treatment	
Item	LG[1]	MG[2]
Ingredient, % of DM		
Corn silage	37	29
Prairie hay	53	41
DDGS	10	5
Energy/protein supplement	–	25
Chemical composition, %		
Ash	12.57	9.57
Crude protein	10.49	11.57
ADF	36.97	29.38
NDF	61.12	50.68
Fat	1.98	3.48
Calcium	0.95	0.78
Phosphorus	0.40	0.41

[1]Low gain: Heifers fed a basal total mixed ration (TMR) contained a commercially available mineral supplement (Purina® Wind & Rain® Storm® All-Season 7.5 Complete Mineral, Land O'Lakes Inc., Arden Hills, Minn.) fed at a rate of 4 ounces per head per day, targeting gain of 0.63 lb/d.
[2]Moderate gain: Heifers fed basal TMR plus an energy/protein supplement formulated with a blend of ground corn, DDGS, wheat midds, fish oil and urea, targeting gain of 1.75 lb/d.

tion of colostrum and milk (fat, protein, somatic cell count [**SCC**], milk urea nitrogen [**MUN**] and other solids).

Heifer BW was analyzed as repeated measures in time using the MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) for effects of treatment, day and a treatment × day interaction. Colostrum and milk data were analyzed using the GLM procedure of SAS with the effects of treatment, day/oxytocin and their interaction. Heifer was considered the experimental unit in all analyses and significance was set at $P \leq 0.05$.

Results and Discussion

Heifer body weight was affected by a treatment × day interaction ($P < 0.01$), being similar at initiation of treatment, diverging by day 14 ($P = 0.01$) and was 122.1 lbs. greater for MG heifers at day 84 ($P < 0.01$; Figure 1). Although heifers were managed as a single group beginning at day 85, the weight divergence continued throughout calving until weaning, at which times heifers in the MG treatment remained 90.4 pounds ($P < 0.01$) and 56.1 pounds ($P = 0.04$) heavier than LG heifers, respectively.

In colostrum (Table 2), we observed an effect of maternal treatment on SCC ($P = 0.05$), which was lower in MG heifers than in LG heifers; however, the percent of fat ($P = 0.11$), protein ($P = 0.40$), other solids ($P = 0.17$) and MUN ($P = 0.29$) were not influenced by rate of gain during the first 84 days of gestation. Somatic cells in colostrum and milk include epithelial cells and leukocytes (macrophages, neutrophils and lymphocytes), with the majority of somatic cells in milk being leukocytes (Kelly et al., 2000).

Consequently, SCC is an indicator of colostrum and milk quality, and a measure of inflammation and infection in the udder. Somatic cell score is greater in colostrum than in milk, which may be caused by cells passing through leaky tight junctions present in the mammary epithelium, which close when milk production increases (McGrath et al., 2016).

Maternal dietary treatment did not affect milk production on day 62 postpartum ($P = 0.67$; LG: 10.6 ± 0.91 pounds/day; MG: 11.2 ± 0.92 pounds/day), but influenced milk composition on days 62 and 103 postpartum (Table 3). Moderate-gain heifers had a greater percentage of milk protein ($P < 0.01$) and other solids ($P = 0.03$) than LG heifers.

Further, the percent of fat and other solids in milk decreased from

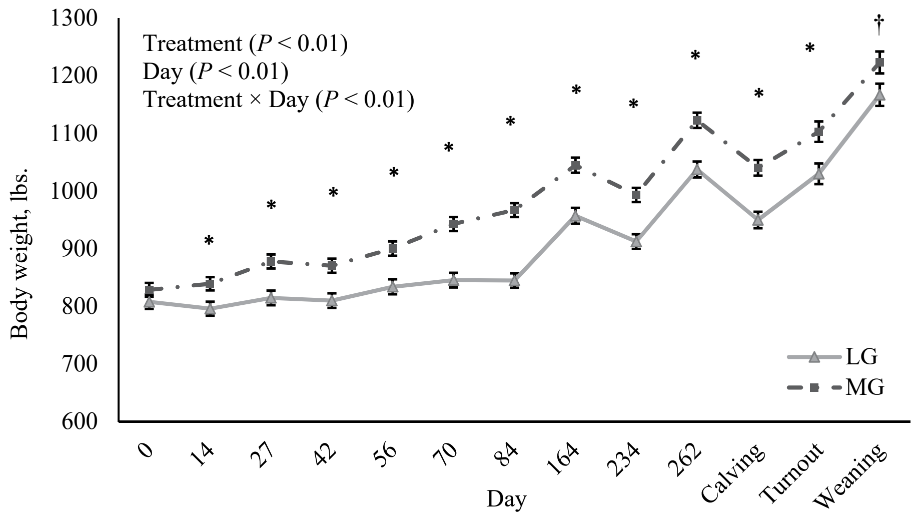

Figure 1. Impact of nutritional treatment on body weight of heifers managed at two rates of gain (low gain [LG], 0.63 lb/d; moderate gain [MG], 1.75 lb/d) for 84 days, followed by common management for the duration of gestation and lactation. *Within day treatments differ (P < 0.01), † with day treatment differ (P = 0.04).

Table 2. Colostrum composition of beef heifers as influenced by rate of gain (low gain [LG], 0.63 lb/d; moderate gain [MG], 1.75 lb/d) during the first 84 days of gestation.

	Treatment[1]			
Item	LG	MG	SEM[2]	*P*-value
Fat, %	5.7	6.7	0.47	0.11
Protein, %	13.6	14.3	0.70	0.40
Somatic cell count, cells × 10^3/mL	6,949	4,776	796	0.05
Milk urea nitrogen,	1.7	0.6	0.83	0.29
Other solids, %[3]	4.3	4.5	0.1	0.17

[1]Treatment: Low-gain heifer (LG) fed a basal TMR contained a commercially available mineral supplement targeting gain of 0.63 lb/d; moderate-gain heifers (MG) fed basal TMR plus an energy/protein supplement targeting gain of 1.75 lb/d
[2]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).
[3]Values for other solids include lactose and ash.

day 62 to day 103 postpartum ($P < 0.01$), whereas the percent of protein in milk and MUN increased for the same time periods ($P < 0.01$). This could be related to the nutritional management of the heifers, as milk composition can be influenced by multiple factors, with milk fat being the component that can vary the most as a result of environmental and physiological factors, especially nutrition (Bauman and Griinari, 2001). Here, heifers received a basal TMR in a dry-lot setting at day 62, whereas they were grazing native range at day 103 postpartum.

At day 103 postpartum, using a sampling technique that included oxytocin administration and an extended lag time of 90 seconds after teat stimulation, we saw an increased percent of milk fat ($P < 0.01$), compared with collecting an immediate sample without oxytocin injection (Table 4). However, oxytocin administration and the extended lag time did not affect the percent of milk protein ($P = 0.98$).

Both observations make sense in regard to the anatomy of the mammary gland and the role that oxytocin plays in the milk ejection process. Regardless of the sampling technique used, milk fat concentrations were extremely low and do not appear representative of the milk fat that calves have access to when compared with results by Kennedy et al. (2019), who reported fat concentrations greater 4% in beef cows (4.11 ± 0.33% for control and 4.21 ± 0.33% for supplement). Therefore, future sampling techniques should focus on milking at minimum an entire quarter to obtain a better representation of nutrients in milk.

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Table 3. Milk composition of beef heifers at days 62 ± 10 and 103 ± 10 postpartum as influenced by rate of gain (low gain [LG], 0.63 lb/d; moderate gain [MG], 1.75 lb/d) during the first 84 days of gestation.

	LG[1]		MG[2]			*P*-values		
Item	d 62[5]	d 103[6]	d 62	d 103	SEM[3]	Treatment	Day	Treatment × Day
Fat, %	0.55	0.35	0.45	0.34	0.044	0.23	<0.01	0.28
Protein, %	2.75	3.0	2.92	3.12	0.045	<0.01	<0.01	0.53
Somatic cell count, cells × 10^3/mL	36.65	88.09	33.59	57.9	28.76	0.55	0.18	0.63
Milk urea nitrogen,	4.11	11.15	3.95	10.11	0.425	0.15	<0.01	0.29
Other solids, %[4]	6.20	6.08	6.26	6.13	0.027	0.03	<0.01	0.87

[1]Low gain: Heifers fed a basal TMR contained a commercially available mineral supplement targeting gain of 0.63 lb/d.
[2]Moderate gain: Heifers fed basal TMR plus an energy/protein supplement targeting gain of 1.75 lb/d.
[3]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).
[4]Values for other solids include lactose and ash.
[5]Milk sample collected at day 62 ± 10 postpartum.
[6]Milk sample collected at day 103 ± 10 postpartum.

Table 4. Percent of milk fat and protein in beef heifers at day 103 ± 10 postpartum as influenced by sampling technique and rate of gain (low gain [LG], 0.63 lb/d; moderate gain [MG], 1.75 lb/d) during the first 84 days of gestation.

	LG[1]		MG[2]			*P*-values		
Item	Pre-Oxytocin[4]	Post-Oxytocin[5]	Pre-Oxytocin[4]	Post-Oxytocin[5]	SEM[3]	Treatment	Oxytocin	Treatment × Oxytocin
Fat, %	0.35	0.88	0.34	1.03	0.078	0.23	<0.01	0.28
Protein, %	3.00	3.00	3.12	3.12	0.043	<0.01	<0.01	0.53

[1]Low gain: Heifers fed a basal TMR contained a commercially available mineral supplement targeting gain of 0.63 lb/d.
[2]Moderate gain: Heifers fed basal TMR plus an energy/protein supplement targeting gain of 1.75 lb/d.
[3]SEM = Standard error of the mean (LG, n = 23; MG, n = 22).
[4]Milk sample collected before injection of 1 mL of oxytocin and a 90-second lag time.
[5]Milk sample collected after administration of 1 mL of oxytocin and a 90-second lag time.

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Timing and duration of maternal nutrient restriction during mid to late gestation influence fetal glucose and amino acid flux in sheep

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The objective of this experiment was to evaluate the effects of nutrient restriction during mid to late gestation on net uterine, fetal and uteroplacental flux of glucose and amino acids. Results from this study demonstrate that timing and duration of nutrient restriction during mid to late gestation influence fetal glucose and amino acid flux, which potentially could influence offspring growth and development.

Summary

Previous research has demonstrated that maternal nutrient restriction during mid to late gestation can influence fetal flux of glucose and amino acids in sheep. However, what is unclear is how the timing and duration of nutrient restriction during midgestation influence net uterine, uteroplacental and fetal flux of glucose and amino acids. On day 50 of gestation, 41 ewes carrying singletons (mean initial body weight [BW] = 106 ± 1.3 pounds) were assigned to these dietary treatments: 100% of nutrient requirements (control; CON; n = 20) or 60% of nutrient requirements (restricted; RES; n = 21) from day 50 to day 90 of gestation (midgestation). At day 90, 14 ewes were euthanized (CON, n = 7; RES, n = 7) and the remaining ewes were subjected to treatments of nutrient restriction or remained on a control diet from day 90 until day 130 of gestation (late gestation; CON-CON, n = 6; CON-RES, n = 7; RES-CON, n = 7; and RES-RES, n = 7) and euthanized for sample collection. We found that maternal nutrient restriction during midgestation increases fetal glucose flux, but maternal nutrient restriction during late gestation decreases fetal glucose flux. Fetal amino acid flux was decreased with nutrient restriction during midgestation; however, this was not apparent when fetal amino acid flux was measured on day 130. These data demonstrate that fetal glucose and amino acid flux are influenced by the timing and duration of nutrient restriction during mid to late gestation, which might have implications for offspring growth and efficiency.

Introduction

Several animal models of fetal and placental growth restriction have been developed to better unravel the relationship among uteroplacental blood flow, placental vascularity and nutrient delivery to the fetus. In sheep, increasing uterine blood flow during the last half of gestation is vital for maintaining continual delivery of sufficient oxygen and nutrients to the exponentially growing fetus (Ford, 1995).

Compromised pregnancies show a decrease in umbilical cord blood flow and a decrease in fetal plasma total α-amino acid concentrations (Kwon et al., 2004). Low birth weight offspring from compromised pregnancies have increased incidences of adult onset diseases, poor growth rates and lower daily rates of gross energy accretion.

Limited information is available on uteroplacental nutrient delivery, uptake by the fetus and maternal nutrient supply from compromised pregnancies. Previous research has demonstrated that maternal nutrient restriction can influence net uteroplacental flux of glucose and amino acids in gestating ewes (Lemley et al., 2013). However, what is unclear is how the timing and duration of nutrient restriction during mid to late gestation influences fetal nutrient delivery. The objective of this experiment was to evaluate how nutrient restriction during mid to late gestation influences net uterine, uteroplacental and fetal flux of glucose and amino acids.

Experimental Procedures

Forty-one ewe lambs carrying singletons were mated by natural service, pregnancy was confirmed, and they were housed at the North Dakota State University Animal Nutrition and Physiology Center. On day 50 of gestation, 41 ewes carrying singletons (mean initial BW = 106 ± 1.3 pounds) were assigned to these dietary treatments: 100% of nutrient requirements (control; CON; n = 20) or 60% of nutrient requirements (restricted; RES; n = 21) from day

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50 to day 90 of gestation (midgestation). At day 90, 14 ewes (CON, n = 7; RES, n = 7) were euthanized and the remaining ewes were subjected to treatments of nutrient restriction or remained on a control diet from day 90 until day 130 of gestation (late gestation; CON-CON, n = 6; CON-RES, n = 7; RES-CON, n = 7; and RES-RES, n = 7) and euthanized for sample collection.

On day 90 (n = 14) and day 130 (n = 27), anesthesia was induced with 3 milligrams per kilogram (mg/kg) of BW sodium pentobarbital. A jugular catheter was inserted to maintain anesthesia through intermittent infusion of sodium pentobarbital. The uterus was exposed with a midventral laparotomy for measurements of uteroplacental blood flow, blood collection and fetal extraction as described by Lemley et al. (2012).

Blood serum was analyzed for glucose and amino acids. Net uterine, fetal and uteroplacental flux were calculated as the arteriovenous concentration difference multiplied by blood flow. Positive flux represents tissue uptake whereas a negative flux represents tissue release.

Results and Discussion

Fetal glucose uptake tended to increase ($P = 0.08$) with nutrient restriction during midgestation (Table 1). Nutrient restriction during midgestation decreased ($P \leq 0.05$) uterine and uteroplacental release of total AA and tended to decrease ($P = 0.07$) total AA uptake by the fetus.

Uteroplacental release and fetal uptake of essential AA were decreased ($P = 0.03$) with RES by 53.4% and 45%, respectively. Uterine and uteroplacental release of nonessential AA were decreased ($P = 0.03$) with RES but fetal uptake was not affected ($P = 0.14$).

Nutrient restriction during midgestation increased ($P = 0.04$) fetal glucose flux measured on day 130 (Table 2). This indicates that increased fetal glucose flux resulting from midgestational nutrient restriction is a persistent effect that alters fetal metabolism throughout late gestation, which might suggest that offspring growth and metabolism could be altered.

Nutrient restriction during late gestation decreased ($P = 0.02$) fetal glucose uptake and increased ($P = 0.02$) uteroplacental glucose uptake. Bidirectional changes in fetal glucose flux resulting from maternal nutrient restriction during either midgestation (increase) or late gestation (decrease) suggests that programming outcomes for offspring is dependent on the timing and duration of maternal nutrient restriction.

Uterine, uteroplacental and fetal fluxes of total, essential or nonessential amino acids were not influenced ($P > 0.08$) by maternal nutrient restriction during mid to late gestation (Table 2). These data indicate that the decreased fetal essential amino acid flux that occurs with nutrient restriction during midgestation does not persist during late gestation. This might suggest that uterine and umbilical blood flows, placental amino acid metabolism and/or fetal metabolism adapt to meet amino acid requirements of the placenta and the fetus to support proper growth and development.

Acknowledgments

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Table 1. Effects of maternal nutrient restriction during midgestation on uterine, fetal and uteroplacental flux of glucose and amino acids (AA) in sheep.[1]

	Midgestation[1]			
Item	CON	RES	SEM[2]	*P*-value
Glucose flux, µmol/min				
Uterine	47.3	44.6	24.3	0.94
Fetal	-86.8	5.23	34.4	0.08
Uteroplacental	134	39.3	45.1	0.15
Total AA flux, µmol/min				
Uterine	-83.5	-39.6	14.4	0.05
Fetal	122	74.3	17.0	0.07
Uteroplacental	-200	-105	26.1	0.02
Essential AA flux, µmol/min				
Uterine	-17.9	-7.45	6.33	0.25
Fetal	53.7	29.6	6.74	0.03
Uteroplacental	-71.6	-33.4	9.54	0.02
Nonessential AA flux, µmol/min				
Uterine	-65.6	-32.1	9.58	0.03
Fetal	68.2	44.8	10.6	0.14
Uteroplacental	-134	-71.5	18.0	0.03

[1]Treatments: CON = control, 100% of National Research Council (NRC) requirements; RES = restricted, 60% of NRC requirements.
[2]CON, n = 7; RES, n = 7.

Table 2. Effects of maternal nutrient restriction during mid to late gestation on uterine, fetal and uteroplacental flux of glucose and amino acids (AA) in sheep.

	Mid to late gestation[1]							
	CON		RES			*P*-value		
Item	CON	RES	CON	RES	SEM[2]	MG Trt	LG Trt	MG x LG Trt
Glucose flux, µmol/min								
Uterine	139	227	-3.90	63.5	116	0.17	0.48	0.92
Fetal	47.0	-185	227	13.7	92.7	0.04	0.02	0.92
Uteroplacental	91.8	412	-231	49.7	127	<0.01	0.02	0.87
Total AA flux, µmol/min								
Uterine	156	22.8	-119	-69.2	136	0.17	0.75	0.48
Fetal	170	350	207	257	97.4	0.76	0.22	0.49
Uteroplacental	-14.4	-327	-326	-326	173	0.35	0.35	0.35
Essential AA flux, µmol/min								
Uterine	54.0	53.1	-24.7	18.5	32.8	0.08	0.50	0.48
Fetal	53	111	66.2	94.8	28.6	0.96	0.12	0.60
Uteroplacental	0.852	-57.7	-90.9	-76.2	46.4	0.22	0.62	0.41
Nonessential AA flux, µmol/min								
Uterine	102	-30.3	-94.2	-87.7	116	0.26	0.57	0.53
Fetal	117	239	141	162	73.4	0.71	0.31	0.48
Uteroplacental	-15.3	-269	-235	-250	137	0.45	0.31	0.37

[1]Treatments: CON = control, 100% of NRC requirements; RES = restricted, 60% of NRC requirements. The second row is midgestational treatments (MG Trt) and the third row is late gestational treatments (LG Trt).
[2]CON-CON, n = 6; CON-RES, n = 7; RES-CON, n = 7; RES-RES, n = 7.

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Managing what you measure: Current and historical Cow Herd Appraisal Performance Software (CHAPS) benchmarks provide reliable data for making herd management decisions

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The Cow Herd Appraisal Performance Software (CHAPS) has been used by beef producers and Extension professionals for more than 35 years. CHAPS provides industry standards and reliable data to enable producers to make informed management decisions. We present the 2021 CHAPS benchmarks along with five-year average percentiles for each benchmark. Additionally, we present a snapshot of the benchmarks during the past 20 years for historical reference. As we move forward with an update to the CHAPS program, we continue to provide producers with an effective tool to manage what they measure.

Summary

The Cow Herd Appraisal Performance Software (CHAPS) has been used as a herd management tool by beef producers and Extension professionals since 1985. Each year, producers submit herd data for CHAPS analysis, including calving distributions, reproductive percentages, and mean weights, growth and ages. CHAPS data specialists compile herd data to calculate yearly averages and the CHAPS benchmarks are calculated as five-year rolling averages of the yearly herd averages. As industry standards, the CHAPS benchmarks help producers set goals and manage their herds to achieve these goals. We present the 2021 CHAPS benchmarks as five-year averages (means), with five-year average minimums, maximums, and 25th, 50th (median) and 75th percentiles, as well as historical benchmarks from 2000, 2005, 2010, 2015 and 2020. We are updating CHAPS from a desktop program to a web-based application to improve usability and data access for producers and will continue to provide additional data and tools to enable producers to better manage their herds. Accompanying the release of the web-based CHAPS, NDSU Extension personnel will lead workshops to navigate producers through the updated program, highlight new features and demonstrate the importance of record-keeping to help producers achieve their goals.

Introduction

NDSU Extension and the North Dakota Beef Cattle Improvement Association developed the Cow Herd Appraisal Performance Software (CHAPS) as a beef herd management tool to collect, store and evaluate beef production data to establish reproduction and production benchmarks (Ramsay et al., 2016; Ringwall, 2018). CHAPS provides vital information about herd performance to help producers manage what they measure through solid data.

The CHAPS program and its development have been described previously (Ramsay et al., 2016). Briefly, CHAPS calculates individual herd calving distribution, reproductive percentages (pregnancy, pregnancy loss, calving, calf death loss, weaning and replacement percentages), and production benchmarks (herd average birth and weaning weights, average daily gain and weight per day of age, frame score, age at weaning, cow age, weight and condition, and pounds weaned per cow exposed).

Yearly averages are calculated from individual herd averages; CHAPS includes herds with a minimum of 50 cows and three consecutive years of data submitted to the CHAPS program. Each year, five-year average benchmarks are calculated from the previous five yearly averages.

The five-year benchmarks are the foundation of CHAPS and guide herd management decisions for CHAPS producers. Understanding the CHAPS benchmarks in terms of five-year average minimum, maximum and percentiles also may provide useful information to producers. Many beef producers, who use breed association expected progeny difference (EPD) percentile tables, which rank sires (Ringwall, 2014), could see the benefit of further un-

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derstanding where their commercial herd ranks among CHAPS herds.

We are updating CHAPS from a desktop program to a web-based application, which ultimately will provide remote access to CHAPS and ensure safe, secure, centralized data storage. Improving the ease with which producers can record data is expected to increase data collection, allow for better data management and help producers make informed herd management decisions (Schulz et al., 2021).

Experimental Procedures

CHAPS-selected herds had a minimum of 50 cows and three years of data submitted to the program; yearly averages were calculated from the selected herds. The 2021 benchmarks were calculated as an average of the previous five yearly values (2016, 2017, 2018, 2019 and 2020) for each reproduction or production trait.

We present 2021 benchmark data for overall calving distribution (%) at 21 days, 42 days, 63 days and after 63 days, as well as heifer (early, 21 days and 42 days) and mature cow (21 days and 42 days) calving distributions. Reproductive percentages include pregnancy, pregnancy loss, calving, calf death loss, weaning and replacement percentages.

Weight and growth benchmarks (reported in pounds) include birth and weaning weights, average daily gain, weight per day of age, frame score, age at weaning (day), and cow age (year), weight and condition, and pounds weaned per cow exposed. Calculations are described in Ramsay et al. (2017a, 2017b, 2017c). Additionally, we report female culling percentages calculated as the sum of culled breeding females relative to the number exposed to at least one bull.

In addition to the five-year benchmarks, we calculated five-year average minimum and maximum benchmarks as well as the five-year average 25th, 50th (median) and 75th percentiles for each benchmark. We also present historical five-year benchmarks from 2000, 2005, 2010, 2015 and 2020, representing yearly averages of CHAPS data collected from 1995 until 2019. Some of this historical data has been summarized previously (Ramsay et al., 2017d).

Results and Discussion

The CHAPS benchmarks were derived from 57,271 cows exposed to bulls from 2016 to 2020. We present the 2021 benchmarks as well as the five-year average minimums, maximums and percentiles (Table 1). The percentiles reflect the distribution of the CHAPS benchmarks. The 50th percentiles (median) and 2021 benchmarks (mean) are similar, indicating a symmetrical distribution of the data and validating the continued use of five-year means in computing the five-year average benchmarks.

In some cases, the benchmark percentiles reflect a wide distribution (minimum to maximum) of benchmark values (for example, early heifer calving distributions range from 0% to 98%), whereas others are more narrow. For some benchmarks, a lower percentile indicates lower performance (e.g. pregnancy, calving and weaning percentages, most calving distributions, and weaning weights and weight gains). For other benchmarks, lower percentiles are more favorable (e.g. pregnancy and calf death loss percentages, late calving distribution, age at weaning). Benchmark percentiles may provide producers with a further incentive to improve their herds beyond the benchmark averages.

For a historical perspective, we present CHAPS benchmarks from 2000, 2005, 2010, 2015 and 2020 (Table 2), representing 97,408, 80,274, 91,832, 76,235 and 60,827 cows exposed to bulls, respectively. Most benchmarks improved from the year 2000, possibly reflecting improvements in data acquisition and comprehension, which resulted in subsequent improvements in management after 2000.

From 2005 until 2020, some of the benchmarks showed slight changes through time, increasing (weaning weights, early and 21-day calving distribution, pregnancy, calving and weaning percentages), or decreasing (birth weight, late calving distribution), while others remained relatively stable (pregnancy loss, female replacement, average daily gain [ADG], weight per day of age [WDA], frame score). Similarly, these changes suggest improvements by CHAPS producers through informed management.

As we reflect on historical data trends and update CHAPS to better serve the technological needs of producers, we remain committed to providing an effective tool for producers to better manage what they measure through solid data.

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Table 1: 2021 Cow Herd Appraisal Performance Software (CHAPS) benchmarks (five-year rolling average of yearly herd averages from 2016 to 2020), including Standardized Performance Analysis (SPA) and Critical Success Factors (CSF) as well as five-year average minimums (min.), maximums (max.) and percentiles (25th, 50th – median, 75th).

	2021 Benchmark	PERCENTILES				
		min.	25th	50th	75th	max.
SPA						
pregnancy, %	94.3	82.0	91.6	94.7	97.0	100
pregnancy loss, %	0.74	0	0	0.1	0.9	7.2
calving, %	93.6	79.4	91.0	94.3	96.5	100
calf death loss[a], %	3.1	0	1.5	2.6	3.7	12.3
calf crop – weaning, %	91.4	75.9	89.1	92.0	94.1	100
female replacement, %	16.0	2.0	12.4	15.0	17.3	41.5
calf death loss[b], %	3.3	0	1.5	2.8	4.1	13.1
age at weaning, day	190	147	168	190	205	268
calving distribution, %						
21 days	63.6	17.1	54.6	66.8	74.6	90.3
42 days	88.8	47.2	86.0	90.6	93.5	99.7
63 days	96.5	67.6	95.5	98.1	99.4	100
after 63 days	3.5	0	0.5	1.9	4.0	32.4
weaning weight, lb.						
Steers	592	448	536	569	599	761
Heifers	553	431	510	543	578	712
Bulls	606	428	582	642	675	756
all calves	564	440	526	560	606	735
pounds weaned/cow exposed, lb.	509	358	465	509	545	686
CSF						
ADG, lb.	2.6	1.9	2.4	2.6	2.8	3.1
WDA, lb.	3.0	2.3	2.8	3.1	3.3	3.6
birth weight, lb.	82	72	79	82	85	95
adjusted 205-day weight[c], lb.	643	498	603	654	680	769
frame score[c]	5.5	4.2	4.9	5.7	6.0	6.3
heifers calving, %						
Early	42.3	0	13.4	42.1	69.3	98.0
21 days	77.7	22.4	69.8	83.0	93.3	100
42 days	91.3	48.6	87.7	96.5	100	100
cows calving, %						
21 days	60.6	10.2	49.9	63.8	75.4	90.2
42 days	87.9	42.6	85.05	89.9	94.15	99.6
cow age, year	5.6	3.6	5.2	5.6	6.0	7.4
cow weight, lb.	1,423	1,185	1,390	1,427	1,480	1,590
cow condition score[c]	5.9	5.5	5.6	6.0	6.1	6.4
culled[d], %	13.4	1.0	9.1	12.4	15.2	39.0

[a]relative to the number of females exposed
[b]relative to the number of calves born
[c]BIF Guidelines (2021)
[d]additional benchmark (not historically provided)

Table 2: Historical Cow Herd Appraisal Performance Software (CHAPS) benchmarks (five-year rolling averages of previous five years of data), including Standardized Performance Analysis (SPA) and Critical Success Factors (CSF), reported at five-year intervals from 2000 until 2020.

	2020	2015	2010	2005	2000
SPA					
pregnancy, %	94.0	93.5	93.8	93.4	92.4
pregnancy loss, %	0.7	0.6	0.7	0.7	0.8
calving, %	93.4	92.9	93.1	92.8	91.7
calf death loss[a], %	3.0	3.4	3.1	3.1	3.9
calf crop – weaning, %	91.3	90.4	91.1	90.3	88.6
female replacement, %	15.3	15.2	15.2	15.1	18.7
calf death loss[b], %	3.2	3.7	3.4	3.3	4.3
age at weaning, days	191	192	189	192	197
calving distribution, %					
21 days	63.6	62.2	63.9	62.4	55.1
42 days	88.5	87.2	88.1	86.4	84.2
63 days	96.6	95.8	95.7	94.6	94.4
after 63 days	3.4	4.2	4.3	5.4	5.6
weaning weight, lb.					
Steers	590	567	574	562	551
Heifers	550	537	546	545	524
Bulls	600	595	610	618	586
all calves	562	555	565	558	542
pounds weaned/cow exposed, lb.	507	495	505	500	475
CSF					
ADG, lb.	2.5	2.5	2.5	2.5	2.3
WDA, lb.	3.0	2.9	3.0	3.0	2.8
birth weight, lb.	82	83	86	88	87
adjusted 205-day weight[c], lb.	638	620	637	627	595
frame score[c]	5.4	5.4	5.8	5.5	5.8
heifers calving, %					
Early	42.8	37.3	37.5	35.0	30.1
21 days	78.0	72.2	71.6	71.2	69.9
42 days	89.4	86.4	85.5	84.6	88.2
cows calving, %					
21 days	60.5	59.1	62.8	59.7	51.8
42 days	87.7	86.0	85.7	85.5	83.1
cow age, year	5.6	5.6	5.7	5.6	5.4
cow weight, lb.	1,416	1,411	1,400	1,378	1,308
cow condition score[c]	5.9	5.9	5.7	5.4	5.0
culled[d], %	12.7	13.2	13.9	13.8	14.8

[a]relative to the number of females exposed
[b]relative to the number of calves born
[c]BIF Guidelines (2021)
[d]additional benchmark (not historically provided)

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Effects of cow size on measures of efficiency in lactating multiparous crossbred beef cattle

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The objective of this study was to determine the effect of cow size on measures of efficiency associated with cow-calf operations. Generally, larger cows consumed a greater number of pounds of feed and weaned heavier calves, while smaller cows consumed a greater percentage of body weight of feed while weaning a larger percentage of body weight.

Summary

Sixty multiparous cows (aged 5 to 6 years) of varying frame scores (FS; 5.17 ± 1.38) were used to examine relationships among body size (body weight [BW], FS, body volume [V]) and cow efficiency. Dry-matter intake (DMI) and BW change were monitored during the 64-day experiment beginning one month prior to bull turnout. Cows were fed a forage-based diet with ad libitum access that was monitored using the Insentec feeding system. Average BW was collected (ABW; 1,459 ± 205.7 pounds) using the average of the two-day beginning and end BW. Measurements collected included body length, hip height, and heart, mid and flank girth. Measurements were collected at the beginning and end of the experiment, with measurements being used to calculate average V (166 ± 25.5 gallons). Calf BW was collected at the time of weaning. Positive correlation coefficients were found between DMI in pounds (lbs) and ABW, FS and V ($P < 0.001$; r = 0.84, 0.74, 0.81). The DMI (% of BW) tended to be negatively correlated with ABW and V ($P = 0.08, 0.09$; r = -0.24, -0.23). We observed positive correlation coefficients ($P \leq 0.05$; r = 0.33, 0.28, 0.26) between WW (lbs) and negative correlation coefficients ($P \leq 0.05$; r = -0.63, -0.57, -0.65) between WW (% of ABW) and ABW, FS and V. We saw a positive correlation coefficient ($P = 0.04$; r = 0.26) between calf ADG and ABW, and a tendency for a positive correlation coefficient ($P = 0.09$; r = 0.23) between calf ADG to weaning and FS. The observed correlation coefficients generally suggest that larger cows consume more pounds of feed and wean heavier calves with greater ADG to weaning, whereas smaller cows tend to consume more feed as a percentage of BW and wean a greater percentage of cow BW. Further research is needed on the complex relationship between cow size and efficiency.

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Introduction

In a cow-calf production setting, the calf is considered the output as opposed to the growth of the animal itself. As calves often are sold at weaning, achieving a high weaning weight (WW) comes with increased revenue. Costs that can be overlooked are those associated with the production of the calf, specifically feed intake of the dam, and this is often the largest cost within a cow-calf operation (Klosterman, 1972).

A common perception with cow-calf operations is that larger cows will wean larger calves, which has, in turn, led to larger cows being more favorable. While the perception is that larger cows are more efficient, some also have questioned if, when after all outputs and inputs are considered, smaller cows are in fact more efficient when weaning a calf and for profitability (Klosterman, 1972; Doye and Lalman, 2011).

This "argument" has resulted in increased interest in investigating the effect of cow size on efficiency. Determining the optimal type of cow to achieve maximum efficiency would provide producers with the ability to maximize profits.

Efficiency is a complex concept, with a general definition of the ratio of outputs to inputs. In cow-calf operations, common measures of efficiency include the WW of the calf compared with the size of the cow and/or the amount of feed consumed by the cow (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016). The objective of this study was to examine the relationship of cow size and efficiency in a cow-calf operation through the measurement of feed intake of the cow and calf WW.

Experimental Procedures

Sixty multiparous cows (1,459 ± 205.7 pounds; 5 to 6 years) accompanied with their calves were used in the experiment. Cows were housed at the NDSU Beef Cattle Research Complex (BCRC) for the duration of the experiment. Fifteen pairs were housed per pen, with four pens total and one separate calf pen per two pens where calves had access to grass hay.

Cows received a forage-based diet for ad libitum intake designed to meet estimated requirements (Table 1). Dry-matter intake (DMI) was monitored using the Insentec automated feeding system (Hokofarm group B.V., Marknesse, Netherlands). All cows had a predetermined body frame score, calculated based on hip height and age at weaning using BIF equations.

Cow body weight (BW) was taken on two consecutive days at the beginning and end of the experiment and on days one and two and days 63 and 64. Body measurements were collected at the beginning and end of the experiment. Calves were weighed upon arrival at the BCRC, twice in the middle of the experiment during a weigh suckle weigh procedure, and were weighed at the time of weaning (weaning weight).

Body size characteristics examined were average BW, body volume and frame score. Body volume was calculated using body measurements: body length, and heart, mid and flank girth, with the average of heart and flank girth representing the end girth.

Measures of efficiency included DMI as pounds and as a percent of cow BW, and calf WW as pounds and as a percent of cow BW. Phenotypic correlations between body size and measures of efficiency traits were determined using Proc MANOVA in SAS and correlations were spearman correlations.

Results and Discussion

Descriptive statistics for measures of efficiency traits are presented in Table 2 and correlation coefficients are presented in Table 3. Overall, larger cows consumed a greater amount of feed in pounds, compared with smaller cows ($P < 0.001$), while smaller cows consumed a greater percentage of BW of feed ($P < 0.001$). Smaller cows tended to wean a smaller calf, compared with larger cows ($P = 0.06$); however they weaned a larger percentage of BW ($P = 0.05$).

Three measurements were chosen to be included in a prediction equation (R2 = 0.75) for DMI: average BW (ABW), average weight change (AWC) and calf WW (CWW); DMI = 0.629 + 0.02(ABW) + 0.854 (AWC) + 0.015(CWW). A prediction model for DMI provides insight into what factors contribute to differences in DMI and potentially could be used to aid in making decisions relative to feeding and breeding management.

Table 1. Ingredients of diet fed to cows.

Ingredient	% of total diet, DM basis
Hay	68.5
Corn silage	15
Dried distillers grain with solubles	11.5
Fine ground corn	4.72
Salt	0.2
Vitamin premix	0.01
Trace mineral premix	0.05
Monensin premix	0.02

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Table 2. Descriptive statistics of measures of efficiency traits in cows.

Traits	Mean ± SD	Median	Minimum	Maximum
Wt change, lbs.	31.1 ± 45.17	27.6	-77.6	150
AVG Wt change/day, lbs.	0.48 ± 0.705	0.42	-1.21	2.34
DMI, lbs.	35.7 ± 5.247	35.7	22.5	49.6
DMI, % of BW	2.45 ± 0.2	2.45	1.81	2.95
Calf WW. lbs.	509 ± 72.8	507	375	657
Calf WW, % of BW	0.35 ± 0.061	0.36	0.23	0.47
Calf ADG, lbs.	6.59 ±1.036	6.59	4.72	8.82

Measures of efficiency traits across all cows in the experiment include weight change (Wt change), average weight change per day (AVG Wt change/d), dry matter intake as lbs. (DMI) and as percent of body weight (DMI, % of BW), calf weaning weight in lbs. (Calf WW), calf weaning weight as a percent of cow body weight (Calf WW, % of BW) and calf average daily gain (Calf ADG).

Table 3. Phenotypic correlation coefficients between body size and measures of efficiency traits.

Parameters	ABW	VOL	FS
DMI	0.833; <0.001	0.784; <0.001	0.769; <0.001
DMIP	-0.247; <0.001	-0.222; 0.09	-0.110; 0.40
CWW	0.252; 0.06	0.148; 0.26	0.274; 0.03
CWWP	-0.618; 0.05	-0.644; <0.001	-0.505; <0.001
CADG	0.203; 0.12	0.096; 0.47	0.220; 0.09

Body size traits include average body weight (ABW), volume (VOL) and frame score (FS), and measures of efficiency include dry-matter intake (DMI), dry-matter intake as percent of body weight (DMIP), weaning weight (CWW), weaning weight as a percent of cow body weight (CWWP), calf average daily gain (CADG) and residual feed intake (RFI).

Weather variables influence dry-matter intake in beef steers

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The objective of this study was to examine the relationship between weather variables (ambient temperature, range of temperature, solar radiation, dew point and wind speed) and dry-matter intake (DMI). Weather variables interacted and accounted for 44.9% of additional variation in beef steers after accounting for body weight, dietary energy density and time of year effects. This will increase the accuracy of DMI prediction equations for more accurate estimates of nutrient intake and better management of feed resources in beef cattle production.

Summary

Current DMI equations are not adequate for beef cattle in the northern Great Plains. The objective of this study was to account for additional variation in dry-mater intake as a result of weather. Condensed intake data (13,895 steer-week observations) from 790 beef steers collected through an Insentec feeding system from 2011 to 2017 were utilized to examine the relationship between DMI and weather variables. Weather variables modeled were ambient temperature, solar radiation, range of temperature, dew point, wind speed, and two-week and monthly lag of each weather variable listed. We found that weather variables accounted for an additional 44.9% in the variation of DMI after accounting for body weight, dietary energy density and time of year effects. This study has facilitated a better understanding of the weather factors that influence DMI in beef steers, which will help producers manage their feed resources efficiently and improve estimates of nutrient intake.

Introduction

Feed accounts for more than 70% of the cost of production. Any feeding system that will increase the efficiency of feed management will result in reducing the total cost of production. Limited information exists on how weather variables impact DMI in beef steers in the northern Great Plains of North America, where temperature can fall below minus 30 F in the winters.

DMI models developed by the National Research Council (NRC), now called the National Academies of Science, Engineering, and Medicine (NASEM), may not be adequate for these cold temperatures. Furthermore, the effects of some weather factors and their interactions have not been fully studied.

Many factors could affect feed intake, including the following: age, body weight, genotype and phenotype, health, type and quality of feed, and weather factors. All the interactions among these various factors make DMI prediction difficult.

From the weather factors, which are the focus of this report, air temperature has been the principal factor that has been considered by many authors (Mader et al., 2006). Air temperature alone is not enough in describing the thermal environment of cattle (NRC, 1981) and the rate of body heat loss or gain is dependent on wind speed, amount of moisture and other weather variables.

Studies that have examined other weather variables besides temperature were conducted in warmer climates, which are not applicable to the northern Great Plains. This study examined the relationships that exist between weather variables (ambient temperature, solar radiation, range of temperature, dew point and wind speed) and DMI. The cattle industry has changed in many ways through the years, and predicting DMI more accurately will help in improving the accuracy of DMI prediction equations, which will, in turn, help producers plan their feeding programs and improve utilization of feed resources.

Experimental Procedures

Intake data from 790 beef steers, collected through an Insentec feeding system (RIC feeding system; Hokofarm Group, Marknesse, Netherlands) that records individual intake of animals, were analyzed using a linear mixed model of SAS to examine how ambient temperature, range of temperature, solar radiation, wind speed and dew point affect dry-matter intake. Weather variable data were downloaded from the North Dakota Agricultural Weather Network.

For weather variables, we also modeled the two-week lag (average of the previous two weeks) and monthly lag (average of the previous month). All data were condensed from daily to weekly to

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remove day-to-day variation, and we had a total of 13,895 steer-weeks observations. The model used accounted for week of the year, experiment, body weight and dietary energy density. All modeling was done using the MIXED procedures of SAS (SAS Institute Inc., Cary, N.C.).

Results and Discussion

The significant main effect variables in our model that accounted for some variation in DMI are shown in Table 1. The interactions between weather variables that accounted for variation in DMI are shown in Figures 1 and 2.

The interaction between ambient temperature and range of temperature influences DMI (Figure 1a). At cold temperatures and high range (fluctuation) in temperature, we saw a decrease in DMI. At high temperature and higher fluctuation in temperature, DMI increases.

On the other hand, at either low temperature or high temperature with lesser fluctuation in temperature, we observed a minimal effect of DMI. This shows that seasons with higher fluctuation in temperature will have a greater effect on DMI of beef steers. How the interaction between ambient temperature and wind speed influences DMI is shown in Figure 1b.

At low temperature (below 0 F) and lower wind speed, we saw a small decrease in DMI. At low temperatures and high wind speed, we observed a large negative effect on DMI.

On the other hand, from above 0 F temperatures, DMI intake increases with increasing temperature and increasing wind speed, but high temperature and lower wind speed have minimal effect on DMI. Figure 1c shows how the interaction between ambient temperature and dew point influences DMI.

At cold temperature with drier air (lower dew point), we observed a negative effect on DMI. High temperatures with drier air have a positive effect on DMI but as the dew point increases at higher temperatures, DMI decreases. This is likely because at high temperature and high dew point, the air is saturated with moisture and evaporative cooling by cattle is hindered, thereby decreasing their ability to dissipate excessive heat, which directly affects DMI because they must reduce metabolic heat production.

How the interaction between ambient temperature and solar radiation influences DMI is shown in Figure 1d. At low temperature and high solar radiation, we observed an increase in DMI, but at very high temperature and high solar radiation, we saw a decrease in DMI. This suggests that DMI increases on cold and sunny days and DMI decreases on hot and sunny days.

Range of temperature and dew point interact to influence DMI (Figure 2a). When range of temperature is low, we saw little to no effect on DMI at either low or high dew point. As range of temperature increases, dry air (low dew point) has a positive association with DMI, but on the other hand, as range of temperature increases, high dew point has a negative association with DMI.

Wind speed and solar radiation interact to influence DMI (Figure 2b). Low wind speed and low solar radiation have little effect on DMI but DMI decreases with increasing solar radiation and wind speed. This suggests that when the air is hotter than the animal's body, more wind speed increases the temperature of the animal's body rather than dissipate heat, thereby increasing the heat load and resulting in decreased DMI.

This study showed that weather variables interact together to influence DMI and will improve the accuracy of DMI prediction equations. This will help beef cattle producers manage their feed resources efficiently.

Table 1: Model with significant main effects variables that influence DMI in beef steers.

Variable[1]	Estimates	SE	F-value	*P*-value
Intercept	-5.56×10^{0}	1.25×10^{0}		0.002
Week of the year	---	---	32.6	0.0001
BW, lb.				
Linear	4.48×10^{-2}	2.26×10^{-3}	391.2	0.0001
Quadratic	-3.00×10^{-5}	2.26×10^{-6}	155.0	0.0001
Dietary NEm, Mcal/lb.				
Linear	3.84×10^{0}	9.66×10^{-1}	15.8	0.0001
Quadratic	-1.35×10^{0}	2.43×10^{-1}	30.8	0.0001
Ambient temperature, 2-week lag	-1.92×10^{-1}	1.96×10^{-2}	95.6	0.0001
Range of daily temperature, 2-week lag	-1.09×10^{-1}	1.04×10^{-2}	110.1	0.0001
Solar radiation, 2-week lag	1.46×10^{-2}	1.51×10^{-3}	94.6	0.0001

[1]BW = body weight, NEm = dietary net energy of maintenance. Units are F for ambient temperature, range of temperature and W/m^2 for solar radiation.

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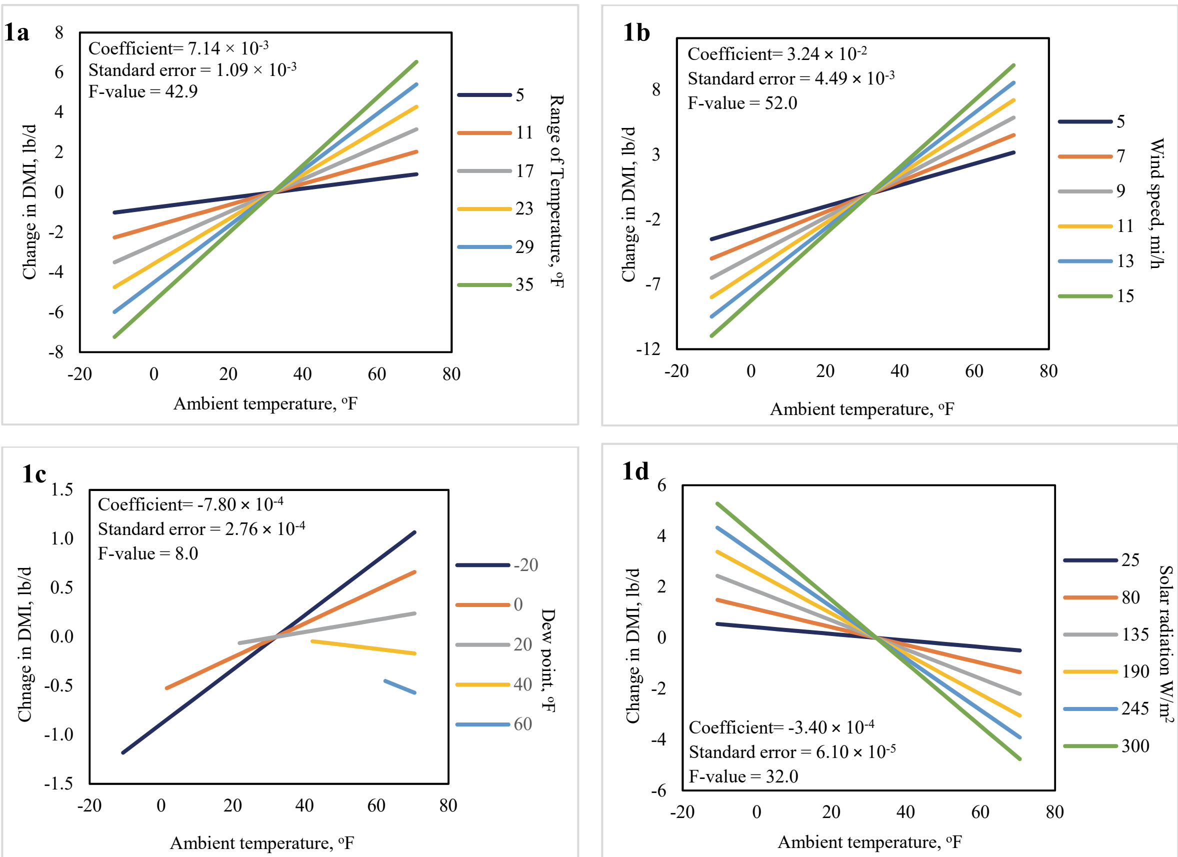

Figure 1: How DMI is influenced by the interactions between ambient temperature and range of temperature (1a), wind speed (1b), dew point (1c) and solar radiation (1d).

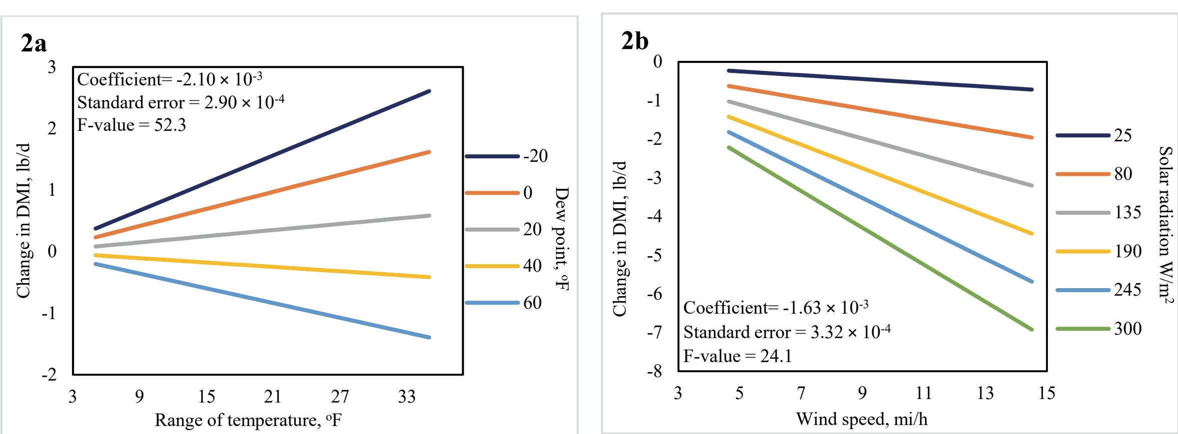

Figure 2: How DMI is influenced by the interaction between range of temperature and dew point (2a), and wind speed and solar radiation (2b).

How average daily gain is influenced by weather variables in beef steers

Mustapha Yusuf[1], Kendall Swanson[1], Lauren Hulsman Hanna[1] and Marc Bauer[1]

The objective of this study was to examine how much variation in average daily gain (ADG) is accounted for by weather variables (ambient temperature, range of temperature, solar radiation, dew point and wind speed). Weather variables accounted for an additional 55.4% of the variation in ADG of beef steers after accounting for body weight, dry matter intake, dietary energy density and the week of the year. This has increased our current understanding of factors influencing ADG, which should be included when beef cattle producers make their ADG projections.

Summary

Average daily gain (ADG) is a measure of performance utilized by beef cattle producers. The objective of this study is to examine how weather variables influence ADG. This study utilized condensed intake data (13,739 steer-weeks observations) from 790 beef steers collected through an individual feeding system to evaluate how weather variables influence ADG. Ambient temperature, solar radiation, range of temperature, dew point and wind speed, as well as their two-week and monthly lag, were modeled while accounting for body weight (BW), dry matter intake (DMI), dietary energy density (NEm) and week of the year. The results from this study show that weather variables account for 55.4% additional variation in ADG. This indicates that weather variables affect ADG and should be included in models used for ADG predictions.

Introduction

In beef cattle production, average daily gain is one of the most important measures used in assessing the productivity of finishing cattle. The amount of energy and other nutrients in the diet for beef cattle is the primary factor influencing growth of the animal (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016). Factors such as genetics, environment, diet, mineral and vitamin supplements, feed additives, implants and ionophores all affect ADG, and expanded modeling of such terms is warranted.

A large component of the environment is weather because weather influences the physiology and thermal balance of an animal. The objective of this study was to evaluate the weather variables that influence ADG. This will improve the accuracy of the estimates utilized by producers in accounting for the quantity of energy required for growth and facilitate better productivity of the herd.

Experimental Procedures

Individual intake data from 790 beef steers collected from 2011 to 2017 through an Insentec feeding system (RIC feeding system; Hokofarm Group, Marknesse, The Netherlands) were utilized for this study (n = 13,739 steer-weeks observations). Body weight, DMI, NEm and week of the year were standard fixed effects that were included (base model), additional variation accounted for by weather variables (ambient temperature, range of temperature, solar radiation, wind speed and dew point) then was evaluated.

For each weather variable, we modeled the direct week, two-week lag (average of the previous two weeks) or monthly lag (average of the previous month) independently. All data were condensed from daily to weekly averages to remove day-to-day variation. All modeling was done using the MIXED procedures of SAS (SAS Institute Inc., Cary, N.C.).

Results and Discussion

The descriptive statistics of the variables used in this study are shown in Table 1. The significant ($P < 0.05$) main effects in our final model are shown in Table 2.

We observed a decrease in ADG with increasing solar radiation and increasing range of temperature (Figure 1a). Solar radiation has been reported to influence cattle by affecting physiology and thermal balance. This is why cattle with access to shade have been observed to perform better than unshaded cattle.

In this study, at dew point temperatures below 27.5 F and increasing solar radiation, we observed an increase in ADG. On the other hand, with dew point temperatures above 43 F and increasing solar radiation, ADG decreased (Figure 1b). The radiant energy from the sun has been known to influence the thermal energy of the animal.

Cattle raised in the northern Great Plains experience long winters

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characterized by prolonged periods of cold. Solar radiation and temperature interacted to affect ADG. We observed an increase in ADG with increasing solar radiation and decreasing temperature (less than 21.7 F).

Average daily gain decreased with increasing temperature and increasing solar radiation (Figure 1c). This explains the impact of ambient temperature and solar radiation on the physiology of beef cattle and how they influence the thermal balance of cattle.

We observed a decrease in ADG with increasing solar radiation and increasing wind speed (Figure 1d). Wind has been reported to have an influence on the thermal environment. In cold environments, high winds make the temperature feel colder, which is generally regarded as wind chill.

The interaction between range of temperature and dew point and its effect on ADG is shown in Figure 2a. Average daily gain increases with increasing dew point and increasing range of temperature. On the other hand, ADG decreases with decreasing dew point and increasing range of temperature. This shows that the range of temperature (fluctuation) in temperature has an impact on the animal because cattle generally take time to fully acclimatize to changes in weather.

The interaction between monthly lag of range of temperature and monthly lag of wind speed and its effect on ADG is shown in Figure 2b. As the range of temperature and wind speed increases, ADG decreases.

Dew point and two-week lag of ambient temperature interacted to affect ADG (Figure 3). At very low (minus 17 F) dew point and low temperature (minus 11 F), ADG is negatively influenced. As the temperature reached 37.9 F, dew point had a small effect on ADG. When the temperature was 70.5 F, a low dew point increased ADG but a high dew point decreased ADG.

No studies have examined the effect of weather variables on ADG of beef steers in the northern Great Plains. The results from this study indicates that ADG is significantly influenced by weather variables and the addition of weather variables should be considered when making ADG predictions for improved accuracy.

Table 1: Descriptive statistics of the variables used in this study.

Variable	Mean	Minimum	Maximum	SD[1]	SE[1]
ADG, lb./day	3.4	-6.70	10.71	0.77	0.006
BW, lb.	1046.0	434.99	1755.01	99.11	0.84
DMI, lb./day	23.6	5.51	47.99	2.74	0.02
NEm, Mcal/lb.	4.4	2.62	5.56	0.24	0.00
Ambient temperature, F					
No lag	28.4	-10.71	70.52	10.45	0.09
Two-week lag	28.1	-5.31	74.41	9.58	0.08
Monthly lag	28.0	-0.31	72.93	9.05	0.08
Range of temperature, F					
No lag	50.8	37.02	66.97	2.66	0.02
Two-week lag	50.5	40.23	60.44	2.24	0.02
Monthly lag	50.3	42.69	59.04	1.76	0.01
Wind speed, miles/hour					
No lag	8.6	4.65	14.52	0.71	0.01
Two-week lag	8.6	5.23	11.10	0.52	0.00
Monthly lag	8.6	6.24	10.38	0.40	0.00
Solar radiation, W/m^2					
No lag	112.8	30.81	297.12	64.00	0.55
Two-week lag	107.3	34.56	271.98	58.57	0.50
Monthly lag	104.5	43.66	256.57	54.34	0.46
Dew point, F					
No lag	19.4	-18.11	57.81	8.92	0.08
Two-week lag	19.5	-12.26	62.53	8.15	0.07
Monthly lag	19.6	-6.90	58.89	7.67	0.07

[1]SD = standard deviation, SE = Standard error

Table 2: Main effects in final model for average daily gain in beef steers.

Variable[1]	Estimates	SE	F-value	*P*-value
Base model	-3.9298	0.4948		
Week of the year			33.39	0.0001
DMI	0.01031	0.002746	14.10	0.0002
BW	0.002927	0.000173	286.10	0.0001
NEm	1.0127	0.1218	68.91	0.0001
Range of temperature, monthly lag	0.2609	0.04637	31.65	0.0001
Absolute dew point	-0.07644	0.005621	184.93	0.0001
Ambient temperature, two-week lag	-0.00838	0.003195	6.87	0.0088
Wind speed, monthly lag	0.3182	0.09289	11.73	0.0006

[1]DMI = dry matter intake, BW = body weight and NEm = dietary net energy of maintenance. Units are lb. for BW, lb./day for DMI, Mcal/lb. for NEm, F for ambient temperature, range of temperature, dew point and miles/hour for wind speed.

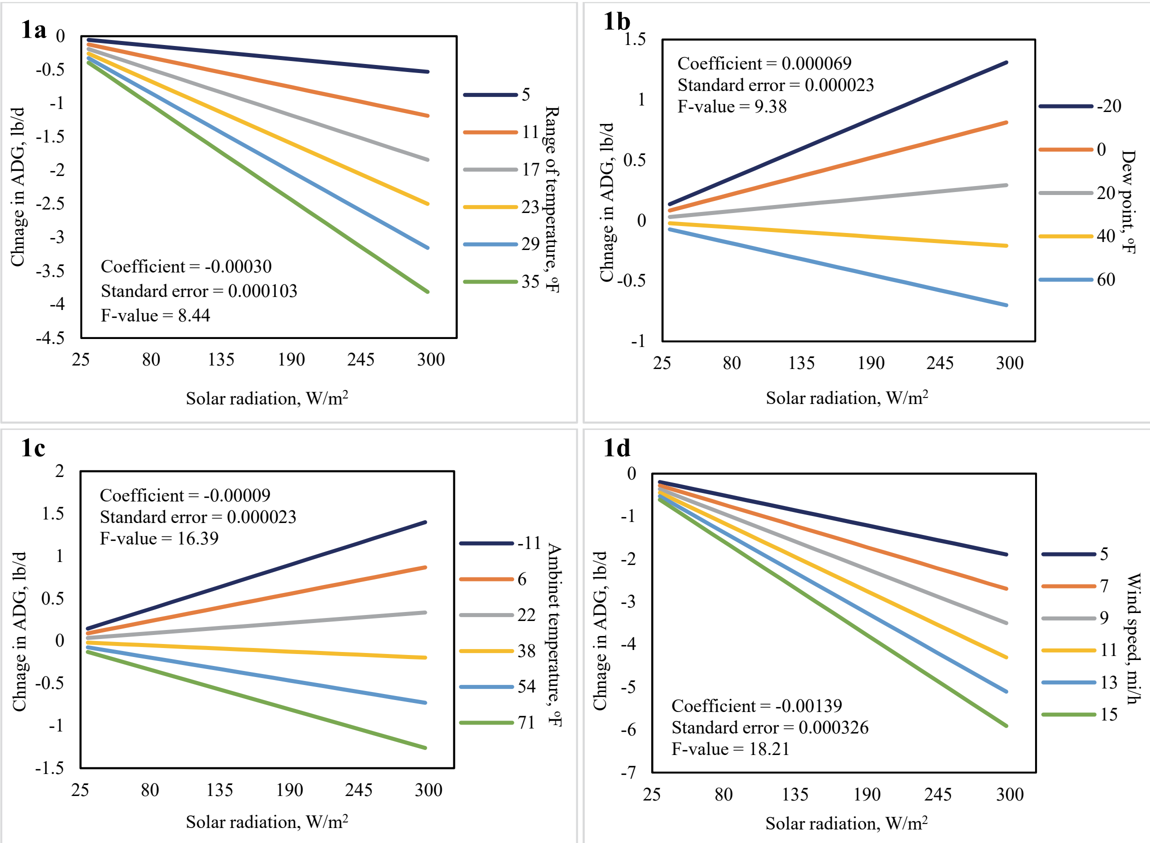

Figure 1: How ADG is influenced by the interaction between solar radiation and range of temperature (1a), dew point (1b), ambient temperature (1c) and wind speed.

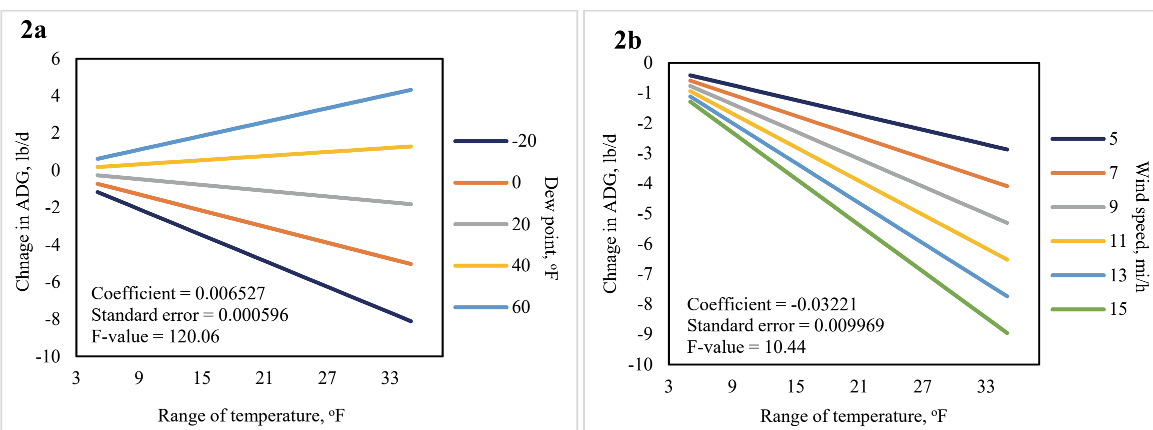

Figure 2: How ADG is influenced by the interaction between range of temperature and dew point (2a), and wind speed (2b).

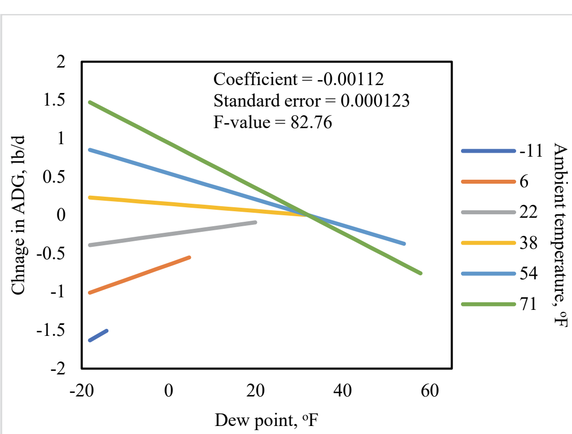

Figure 3: How ADG is influenced by the interaction between dew point and ambient temperature.

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Evaluation of hempseed cake on cattle performance, carcass characteristics, feeding behavior and plasma metabolites in finishing diets

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The objective of this experiment was to evaluate the effects of feeding hempseed cake as a protein source on performance, carcass characteristics, plasma metabolites and feeding behavior of finishing beef heifers. Results from this study suggest that when fed at the same inclusion as dried distillers grains, hempseed cake may result in reduced performance without impacting carcass yield or quality, feeding behavior or plasma total amino acid concentrations in finishing cattle.

Summary

Thirty-one cross-bred heifers were assigned randomly to one of two treatments: a diet containing 20% dried distillers grains plus solubles (DDGS; CON) or 20% hempseed cake (HEMP) on a dry-matter basis. Cattle were fed for 111 days and were slaughtered at the end of the trial to determine potential withdrawal effects of hempseed cake. During the course of the study, body weights (BW) and blood were collected bi-weekly. Feeding behavior was monitored throughout the trial using the Insentec bunk system. Blood samples were processed for the analysis of plasma metabolites including glucose, urea nitrogen (N) and total amino acids (AA). Data were analyzed as a completely randomized design using the MIXED procedure of SAS. Final BW, average daily gain (ADG), feed conversion (F:G) and hot carcass weight (HCW) were reduced by 2.3%, 7.7%, 7.7% and 2.6%, respectively ($P \leq 0.05$), in HEMP cattle, compared with DDGS cattle. Plasma urea N concentration increased ($P < 0.01$) by 21% in heifers fed hempseed cake, compared with DDGS.

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Introduction

Industrial hemp production has been revitalized in the U.S. after it was removed from the list of U.S. Drug Enforcement Agency Schedule 1 drugs as a result of the 2018 Agricultural Improvement Act. A series of pilot studies was allowed under the 2014 Agricultural Improvement Act and led to reinstating industrial hemp production cultivation. Industrial hemp must contain less than 0.3% delta-9-tetrahydrocannabinol (THC), which is the psychoactive component of the hemp plant.

Mechanical processing of the hemp seed for oil extraction has increased with the rise in demand for hemp oil for human use. This process creates a byproduct that is high in fiber and protein (roughly 50% and 30%, respectively) but limited markets are available for it because hemp and hemp byproducts are not an FDA-approved feedstuff for livestock in the U.S.

Because of the nutrient profile of the hempseed byproduct (hempseed cake), ruminants are an ideal target species because of their ability to convert fiber to usable energy. Furthermore, hemp and hemp byproducts are thought to potentially have therapeutic benefits when fed to livestock (Kleinhenz et al., 2020). While feeding hemp byproducts is legal in the European Union (among other places), relatively limited data is available on the nutritive value of hempseed cake as a protein source to beef cattle (Hessle et al., 2008).

Experimental Procedures

Thirty-one cross-bred heifers (initial body weight [BW] = 1,091 pounds; SD = 99) were assigned randomly to one of two treatments: a diet containing 20% DDGS (CON, n = 16) or 20% hempseed cake (HEMP, n = 15) on a dry-matter basis (Table 1). Diets were corn-based (10% roughage) finishing rations formulated to meet or exceed ruminally degradable and metabolizable protein, vitamin and mineral requirements.

Cattle received 36 grams/ton of Rumensin and each diet contained 1% urea. On day one, heifers were implanted with Revalor H. Body weights were collected on days zero, one, two, three, seven, 14 and biweekly until day 98, with the final BW occurring at slaughter (days 112 to 120). Additionally, blood samples were collected via jugular venipuncture and centrifuged to obtain plasma on days zero, two, three, seven, 14, 28, 42, 56, 70, 84 and 98 and were analyzed for glucose and urea N concentrations.

Plasma samples were analyzed for AA concentrations on days zero, seven, 56 and 98. For this report, only total plasma amino acid concentrations are presented.

At the conclusion of the 111-day feeding period, cattle were assigned to slaughter groups on five days within a nine-day window between days 112 and 120. Carcass data were collected after cattle were slaughtered via captive bolt stunning and exsanguination.

Dietary net energy for maintenance (NEm) and net energy for gain (NEg) were calculated using performance data as described by Galyean (2009) and the National Research Council (NRC; 1996). Feeding behavior data were collected using the Insentec bunk system. Data were analyzed using the MIXED procedure of SAS, with initial BW used as a covariate for performance and carcass data and repeated measures were utilized for plasma metabolite data.

Results and Discussion

The nutrient analysis shows that dry matter, crude protein, ether extract and neutral detergent fiber (NDF) concentrations were comparable, while acid detergent fiber (ADF) was 5 percentage units greater (numerically) for the hemp treatment (Table 2). Heifers fed DDGS had greater final BW, average daily gain (ADG) and feed conversion, compared with HEMP cattle ($P \leq 0.05$; Table 3), while dry-matter intake (DMI) was not different between treatments ($P = 0.94$).

The observed lack of effect on DMI is similar to what other authors have reported (Mustafa et al., 1999; Gibb et al., 2005) from cattle fed hempseed meal. Dietary NEm and NEg (megacalorie per kilogram

Table 1. Composition and nutrient composition for treatment diets.

	Treatments	
	Control	Hemp
Ingredient, % of diet DM		
Corn grain	55	55
DDGS[1]	20	0
Hempseed cake	0	20
Corn silage	20	20
Supplement[2]	5	5
Nutrient Analyses[3]		
Dry matter	66.0	65.13
Ash	5.79	6.39
Starch	43.7	43.2
Crude protein	14.8	15.8
Ether extract	3.47	3.38
Neutral detergent fiber	29.1	30.4
Acid detergent fiber	11.4	16.3
Calcium	0.69	0.78
Phosphorus	0.44	0.53
Calcium:Phosphorus	1.56	1.48

[1]Dried distillers grains plus solubles (DDGS).
[2]Formulated to supply monensin (Rumensin-90, Elanco Animal Health, Greenfield, Ind.) at 36 grams/ton. Urea included at 1% of diet DM.
[3]Average of weekly samples.

Table 2. Performance and carcass characteristics between treatments.

	Treatments			
	Control	Hemp	SEM	*P*-Value
Performance[1]				
Initial BW, lb.	1,086	1,095	25	0.80
Final BW, lb.	1,539	1,505	16	0.05
DMI, lb.	31.2	31.1	0.6	0.94
ADG, lb.	4.04	3.73	0.15	0.05
F:G	7.76	8.37	0.26	0.02
NEm, Mcal/lb.	0.87	0.83	0.02	0.02
NEg, Mcal/lb.	0.58	0.54	0.02	0.02
Carcass characteristics[2]				
HCW, lb.	929	904	11	0.03
Dress %	60.4	60.5	0.5	0.90
LM area, inch^2	15.0	14.6	0.4	0.37
Fat thickness, inch	0.68	0.65	0.06	0.61
Marbling score[3]	512	498	14	0.48
Calculated YG[4]	3.41	3.35	0.24	0.81

[1]Performance parameters: Initial body weight (BW), final BW, dry-matter intake (DMI), average daily gain (ADG), feed conversion (F:G), Net energy for maintenance (NEm, Mcal/lb), Net energy for gain (NEg, Mcal/lb).
[2]Carcass characteristics: Hot carcass weight (HCW), dressing percent (Dress %), longissimus muscle area (LM area).
[3]Marbling score: 400 = Slight^{00}, 450 = Slight^{50}, 500 = Small, etc.
[4]Yield Grade (YG) = 2.50 + (0.9843 x rib fat thickness, cm) + (0.2 x 2.5% kidney, pelvic and heart fat), + (0.0084 x hot carcass weight) – (0.496 x LM area, cm^2; USDA, 2016).

Table 3. Plasma metabolite levels between treatments.

	Treatment			P Value[1]				
Metabolite	Control	Hemp	SEM	Trt	Day	Trt x Day	Lin	Quad
Amino acids	2,480	2,431	80.1	0.53	< 0.01	0.10	0.21	0.76
Glucose	87.8	90.1	1.84	0.17	< 0.01	0.21	< 0.01	< 0.01
Urea N	16.2	20.5	0.67	< 0.01	< 0.01	< 0.01	< 0.01	0.18

[1]Linear (Lin) and quadratic (Quad) effects were tested for each variable across days.

[Mcal/kg] of feed, DM basis) was greater for CON, compared with HEMP treatments ($P = 0.02$). While dietary energy is lower for HEMP, compared with the CON diet, the NEm and NEg values for the HEMP diet are comparable to many finishing diets commonly fed.

These performance-based measures of feed energy and availability indicate that finishing cattle performance should be reduced, compared with cattle receiving a finishing ration containing DDGS at the current inclusion rate of 20% (DM-basis). Hot carcass weight (HCW) was greater ($P = 0.03$) in heifers fed DDGS vs. hempseed cake while all other carcass characteristics were not different ($P \geq 0.37$). This agrees with previous research where feeding hemp products did not affect carcass characteristics (Hessle et al., 2008; Gibb et al., 2005).

Feeding behavior was not different between treatments ($P \geq 0.32$; data not shown). While the effect of hempseed cake on cattle feeding behavior has not been reported elsewhere, the lack of effect is not surprising because of the observed lack of difference in DMI. Greater ADF concentration in the HEMP diet, compared with the CON diet, may explain some of the performance differences that were observed in this experiment

Total AA were not different between treatments ($P = 0.53$; Table 4); however, we observed a day effect ($P < 0.01$; Table 3). With some exceptions, the general trend of individual AA concentration in plasma decreased between day zero and seven and then increased from day seven to 56 and 98, surpassing day zero baseline levels. The observed decrease between day zero and seven could be a result of stress/immune response in the heifers, shifting the use of AA toward acute phase protein synthesis rather than growth.

Plasma glucose was not different ($P = 0.17$) between treatments, while urea N increased ($P < 0.01$) in HEMP heifers, compared with CON heifers. Day was significant for glucose and urea N ($P < 0.01$), while an interaction between treatment and day was observed for urea N ($P < 0.01$). The observed greater plasma urea N was likely because the hempseed cake diet had greater CP concentration. This also indicates that the protein with hempseed cake is likely digested and utilized somewhat similarly to the diets containing DDGS.

Further understanding of how hempseed cake influences performance is necessary to better understand the quality of this feedstuff for use in cattle diets. Overall, the results of this study suggest that hempseed cake has lower dietary energy relative to DDGS, while still providing the cattle with adequate nutrition to support acceptable performance of finishing cattle. While industrial hemp byproducts are not an approved feedstuff, these data suggest that, although hempseed cake may have lower nutritional quality and potentially result in marginally lower performance than DDGS, it could be a viable alternative feed source for ruminants depending on availability and cost.

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Discovering value in North Dakota calves: Dakota Feeder Calf Show feedout project XIX, 2020-2021

Karl Hoppe[1] and Dakota Feeder Calf Show Livestock Committee[2]

North Dakota cattle producers are identifying cattle with superior growth and carcass characteristics by participating in the Dakota Feeder Calf Show. Average profitability between consignments from the top five herds and the bottom five herds was $189.03 per head for the 2020-2021 feeding period.

Summary

The Dakota Feeder Calf Show feedout project helps North Dakota cattle producers discover the actual value of their 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. 17, 2020. After a 222-day feeding period with 3.28% death loss, cattle averaged 1379.9 pounds (shrunk harvest weight). Feed required per pound of gain was 7.3 (dry-matter basis). Overall pen average daily gain was 3.27 pounds. Feed cost per pound of gain was $0.58 and total cost per pound of gain was $0.83. Profit ranged from $367.58 per head for pen-of-three cattle with superior growth and carcass traits to $90.65 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

Cow calf produces need to remain competitive with other livestock and poultry in the meat industry. By determining calf value in a feedout program, cow-calf producers can identify superior genetics under common feedlot management. Marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

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.

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. 17, 2020, at the Turtle Lake (N.D.) Weighing Station 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 122, of which 104 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 with Synovex-S, dewormed and injected with a prophylactic long-acting antibiotic.

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 Synovex-Choice on Jan. 12, 2021.

Due to COVID-19 pandemic restricts, no formal meeting was conducted for reviewing cattle while being fed. Instead, the cattle owners were invited to review the calves any time prior to harvest.

The cattle were harvested on May 26, 2019 (117 head). The cattle were sold to Tyson Fresh Meats, Dakota City, Neb., on a grid basis, with premiums and discounts based on carcass quality. One calf was harvest locally due to lameness. 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% of score), marbling score (25% of score) and profit (25% of score) and subtracting index value

[1]Carrington Research Extension Center, NDSU
[2]Turtle Lake, N.D.

for calculated yield grade (25% of score). The Dakota Feeder Calf Show provided awards and recognition for the top-ranking pen of steers.

Results and Discussion

Cattle consigned to the Dakota Feeder Calf Show feedout project averaged 602.5 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on Oct. 17, 2020. After an average 222-day feeding period, cattle averaged 1,374.9 pounds (at plant, shrunk weight). Death loss was 3.28% (four head) during the feeding period.

Average daily feed intake per head was 36 pounds on an as-fed basis and 23.8 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 11 on an as-fed basis and 7.27 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.58. The overall yardage cost per pound of gain was $0.10. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.83.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.031048183* initial calf weight, pounds) + 165.6103046) 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 10.2% Prime, 79.6% Choice (including 22.9% Certified Angus Beef), and 10.2% Select, and USDA Yield Grades at 1.7% YG1, 19.5% YG2, 39.0% YG3, 32.2% YG4 and 7.6% YG5.

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 26, 2021, was $194.43 Choice YG3 base with premiums: Prime $15, CAB $6, YG1 $6.50 and YG2 $3, and discounts: Select minus $14, Standard (no roll) minus $15, YG4 minus $8, YG5 minus $20 and carcasses greater than 1050 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 420 days of age and 1,435.6 pounds per head at harvest. The overall pen-of-three feedlot average daily gain was 3.54 pounds, while weight gain per day of age was 3.30 pounds. The overall pen-of-three marbling score was 543.6 (average choice, modest 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. Average harvest weight, average daily gain and marbling score had higher correlations to profitability than average birth date, average weight per day of age or yield grade.

The top-profit pen-of-three calves with superior genetics returned $367.58 per head, while the bottom pen-of-three calves returned $90.65 per head. The average of the five top-scoring pens of steers averaged $320.86 per head, while the average of the bottom five scoring pens of steers averaged $131.84 per head.

For the pen-of-three competition, average profit was $196.70 per head. The spread in profitability between the top and bottom five herds was $189.02 per head.

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.

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

	Correlation coefficient
Profit and average birth date	-0.3469
Profit and average harvest weight	-0.1216
Profit and average daily gain	0.2183
Profit and weight per day of age	-0.3050
Profit and marbling score	0.4893
Profit and yield grade	-0.4182

Table 1. Feeding performance - 2020-2021 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]	Ave Calculated Yield Grade	Ave Feeding Profit or Loss / Head
1	3.026	28-Feb-20	3.03	1420.8	3.85	741.3	3.531	367.58
2	2.643	21-Mar-20	3.36	1502.5	3.57	656.0	3.380	305.21
3	2.624	10-Mar-20	3.31	1513.3	3.63	629.0	3.247	297.89
4	2.571	2-Mar-20	2.86	1332.5	3.24	544.0	2.663	317.79
5	2.468	14-Apr-20	3.27	1377.5	3.89	580.0	3.972	315.86
Average Top 5 herds	2.666	15-Mar-20	3.165	1429.333	3.635	630.067	3.359	$320.87
6	2.394	16-Mar-20	3.20	1448.3	3.45	605.7	3.804	301.56
7	2.342	16-Mar-20	3.21	1450.0	3.51	582.7	3.413	258.65
8	2.235	3-May-20	3.55	1429.2	3.83	405.0	2.923	257.78
9	2.211	20-Mar-20	3.28	1467.5	3.60	561.0	3.676	243.16
10	2.206	26-Mar-20	3.61	1595.8	3.87	605.3	4.087	224.95
11	2.189	24-Apr-20	3.34	1375.0	3.48	456.0	2.894	241.62
12	2.147	14-Apr-20	3.21	1353.3	3.63	631.7	4.345	234.57
13	2.142	19-Mar-20	3.31	1486.7	3.41	583.7	3.523	210.51
14	2.090	13-Apr-20	3.31	1398.3	3.39	534.3	3.576	229.58
15	2.065	23-Apr-20	3.72	1535.0	4.00	528.0	3.935	199.56
16	1.993	8-Apr-20	3.56	1519.2	3.82	428.0	3.275	195.94
17	1.936	9-May-20	3.48	1375.0	3.56	496.0	3.928	217.25
18	1.842	13-Apr-20	3.08	1302.5	3.58	435.0	3.289	164.94
19	1.829	26-Mar-20	3.14	1387.5	3.40	478.0	3.026	127.65
20	1.815	15-Apr-20	3.08	1296.7	3.34	611.7	4.013	134.38
21	1.793	3-Apr-20	3.79	1641.7	3.62	491.0	4.056	178.84
22	1.768	6-Apr-20	3.46	1489.2	3.54	514.7	4.235	178.87
23	1.757	25-Mar-20	3.31	1460.8	3.34	578.7	4.367	166.50
24	1.667	4-Apr-20	3.14	1354.2	3.04	534.7	3.228	90.65
25	1.535	7-Apr-20	3.47	1490.8	3.34	561.0	5.031	128.59
26	1.282	25-Mar-20	3.75	1660.8	4.10	473.3	5.427	94.60
Average bottom 5 herds	1.602	1-Apr-20	3.425	1491.2	3.473	532.5	4.458	$131.84
Overall average – pens of three	2.101	1-Apr-20	3.30	1435.63	3.54	543.62	3.76	196.70
Standard deviation		17.8	0.23	95.52	0.25	78.09	0.64	72.60
number		26	26	26	26	26	26	26

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

Bulls managed on a negative plane of nutrition for 112 days have increased abundance of mammalian Target of Rapamycin (mTOR) in testicular biopsies

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The objective of the current study was to determine the effects of divergent planes of nutrition in mature beef bulls on nutrient sensing pathways and androgen receptor abundance in testicular tissue. Abundance of a key regulator in nutrient metabolism pathways, mTOR, was decreased in bulls on a positive plane of nutrition, which could contribute to differences in sire fertility or messages carried in sperm to future offspring.

Summary

The objective of this study was to evaluate the influence of divergent plane of nutrition on nutrient sensing pathways and androgen receptor abundance in testicular tissue of bulls. Angus bulls (n = 15; 4 to 5 years old) were randomly assigned to one of two treatments: 1) a positive plane of nutrition managed to gain 12% body weight (BW) over 112 d (POS, n = 8); or 2) a negative plane of nutrition managed to lose 12% BW over 112 days (NEG, n = 7). On day 113, testicular biopsies were performed on all bulls. Parenchyma tissue samples were fixed in formalin, embedded in paraffin, cut at 5 µm and placed on glass slides. Slides underwent processing followed by incubation with antibodies to mammalian Target of Rapamycin (mTOR), phosphorylated mTOR (p-mTOR), or androgen receptor (AR), followed by a fluorescent-tagged antibody. Slides were examined for fluorescent intensity of the specific antibody and optical density was quantified for three to five randomly selected images of seminiferous tubules. The number of Sertoli cells and germ cells within each seminiferous tubule were counted and a ratio of germ cells to Sertoli cells was calculated. No differences were observed between treatments for mTOR (*P* = 0.89), ratio of p-mTOR to mTOR (*P* = 0.32) and AR abundance (*P* = 0.64), or Sertoli and germ cell counts (*P* = 0.78, *P* = 0.35, respectively) within the seminiferous tubules. Similarly, no differences were observed in the interstitial space for mTOR abundance (*P* = 0.86) or AR abundance (*P* = 0.62). However, p-mTOR abundance tended to be increased in the seminiferous tubules (*P* = 0.06) and increased in the interstitial space (*P* = 0.004) of NEG bulls compared with POS bulls. These findings suggest that dietary factors influence testicular abundance of signaling proteins involved in metabolic function of the cell, potentially influencing the developing sperm and ultimately affecting sperm quality, sire fertility, or epigenetic messages carried by sperm to future offspring. The USDA is an equal opportunity provider and employer.

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Introduction

Nutritional management of bulls is an important consideration for producers to achieve optimal herd reproductive performance. The consequence of variable nutritional management strategies on sire fertility and subsequent offspring performance remains underexplored. Previous research conducted in livestock species has demonstrated that nutritional status of sires influences scrotal circumference, sperm number and motility, seminal plasma quality, and DNA damage (Guan et al., 2014).

Sperm production occurs within the seminiferous tubules of the testes and requires various molecular signals to allow for this dynamic process. Sertoli cells (SC) serve as nurse cells within the seminiferous tubule, providing support, nourishment, and protection to developing sperm cells. These cells are enclosed within a blood-testes barrier that eliminates direct contact of tubule cells from circulatory blood. Testosterone produced by the Leydig cells of the interstitial space of the testes is also critical to sperm production and supports SC function via the nuclear transcription factor, androgen receptor (AR; Alves et al., 2013). Mammalian target of rapamycin (mTOR) is a protein kinase involved in the cellular signaling pathways of nutrient metabolism and plays a critical role in sperm production in

SC. Activation via phosphorylation of mTOR is influenced by factors like insulin and insulin-like growth factor 1 (IGF-1), cellular energy level, and amino acids (Saxton & Sabatini, 2017). A reduction in mTOR abundance in SC is associated with reduced metabolic activity of the cell, ultimately leading to reduced sperm production and motility (Oliveira et al., 2017). Nutritional changes of the sire may act at the level of the testes, influencing the nutrient sensing and metabolic capacity of SC to support germ cells (Alves et al., 2013). More specifically, overnutrition in rodent and human models have demonstrated paternal effects of transgenerational transmission of metabolic dysfunction and reproductive performance in their offspring (Fullston et al., 2015). Whether different circulating nutrients attained via divergent sire nutrition can work across the blood testes barrier to influence testicular mTOR or AR abundance and potential impact developing sperm is unknown.

Experimental Procedures

Fifteen Angus bulls of 4 to 5 years of age from the Central Grasslands Research Extension Center near Streeter, ND were utilized for this study. Bulls were randomly assigned to one of two treatments: 1) a positive plane of nutrition managed to gain 12% BW (POS, n = 8); or 2) a negative plane of nutrition managed to lose 12% BW (NEG, n = 7) over a 112-day period prior to the breeding season. Bulls were housed at the Beef Cattle Research Complex in Fargo, ND and individually fed using the Insentec Roughage Intake Control System (Markenese, Netherlands) with feed allocations adjusted bi-weekly to achieve targeted growth trajectory. On day 113, testicular biopsies were performed on all bulls using a procedure modified from Heath et al., (2002). Briefly, bulls were restrained in a hydraulic Silencer chute and the scrotal area was scrubbed with iodine and cleaned with alcohol. At the biopsy target site (approximately 5 cm below the head of the epididymis on the lateral aspect of the left testicle), 3mL lidocaine was administered as a local anesthetic. A 14-guage x 10 cm automatic biopsy need (Accu-Core Single Action Biospy, Inrad, Kentwood, MI) was inserted into the testicle, penetrating the parietal and visceral vaginal tunics and tunica albuginea, with care to avoid the epididymis. Two biopsy cores of parenchyma were collected from the left testicle.

The tissue sample was placed in a 10% formalin fixative solution, embedded in paraffin, cut in 5 µm thick sections using a microtome and placed on a glass slide. Immunohistochemistry on the slides was performed, as previously described (Crouse et al., 2021). Briefly, sections were deparaffinized, rehydrated, and underwent antigen retrieval. Slides were stained with monoclonal antibodies to either mTOR (ab32028; Abcam), p-mTOR (ab109268), or AR (ab74272). This was followed by incubation with IgCF633 fluorescent antibody and counterstaining with DAPI. Images were captured at 40×s magnification with an inverted microscope with laser scanning head attachment. Testicular parenchyma consists of 2 distinct regions, the seminiferous tubule containing SC and developing sperm, and the interstitial space, or space between the tubules (Fig. 1). For each bull, three to five seminiferous tubules were randomly selected for image capture. The image was further processed with image analysis software to measure optical density of fluorescence staining within the seminiferous tubule and interstitial space, which is defined as the relative fluorescence intensity of staining divided by the pixel area of the selected field. Sertoli cells were characterized by the presence of AR within the nucleus, with remaining nuclei in the tubule characterized as a germ cell. The number of SC and germ cells per seminiferous tubule were counted and a ratio generated by dividing the number of germ cells by number of SC.

Data were analyzed using the GLM procedure of SAS (Ver.9.4, SAS Inst. In., Cary NC) for the effect of plane of nutrition (POS or NEG) with bull as the experimental unit. Significance was set at $P \leq 0.05$ and tendency at $0.05 < P \leq 0.10$. Data are presented as means ± standard error (SE).

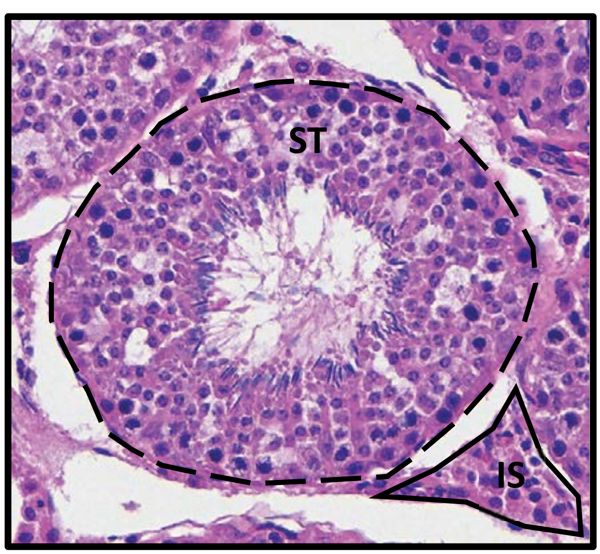

Figure 1. Histology of the testicle. The seminiferous tubule (ST; dashed black line) is the circular structure in the middle of the image, within which Sertoli cells nourish the developing sperm. The interstitial space (IS; solid black line) is the space between ST where testosterone is produced by Leydig cells. The contents of the seminiferous tubules are protected from blood circulation though a mechanism called the Blood-Testis-Barrier.

Results and Discussion

No differences were observed between treatments for the measurement of optical density fluorescent staining for total mTOR within the seminiferous tubules (*P* = 0.89) or in the interstitial space (*P* = 0.86; Table 1; Fig. 2C – D). However, p-mTOR was increased in the interstitial space (*P* = 0.0037) and tended to be increased in the seminiferous tubules (*P* = 0.06) of NEG bulls compared with POS bulls (Table 1; Fig. 2A – B). No differences were observed for AR between treatments within the seminiferous tubules (*P* = 0.64) and interstitial space (*P* = 0.62; Table 1; Fig. 2E – F). The number of Sertoli cells (*P* = 0.78) and germ cells (*P* = 0.35) per seminiferous tubule, as well as the ratio of germ cells to Sertoli cells (*P* = 0.21) were not different between treatments (Table 2).

In the presence of elevated nutrient levels, mTOR abundance and activity is increased to aid in regulation of these key metabolic pathways (Saxton & Sabatini, 2017). Interestingly, although POS bulls had increased concentrations of key mTOR signals (amino acids and IGF-1) in the blood, the abundance of p-mTOR within the seminiferous tubules and interstitial space was reduced when compared to NEG bulls (Table 1; Fig. 1A – B). While this reduction is contrary to the anticipated elevated abundance, previous research has demonstrated decreases of mTOR abundance in the Sertoli cells of rats fed a high-fat diet (Cui et al., 2017). In this experiment, POS bulls may be experiencing similar dysregulation of mTOR activity as a result of alterations in circulating metabolites in the blood and subsequent weight gain. This may be contributing to dysregulation of these nutrient sensing pathways which could alter metabolism in the testes.

A lower germ cell to Sertoli cell ratio may be indicative of decreased metabolic capacity of Sertoli cells to provide support to the germ cells. However, in this experiment, no differences were observed between POS and NEG bulls for number of germ cells and SC, as well as the ratio (Table 2). Guan et al. (2016) reported similar findings in sheep models, demonstrating no effects of over- or undernutrition on the number of Sertoli cells in mature rams. While no treatment differences were observed, nutrient availability has been demonstrated to impact sperm quality and cause DNA damage (Guan & Martin, 2017).

No differences were observed in AR abundance in the seminiferous tubules and interstitial space between treatments (Table 1). However, AR localization in the nuclei has been demonstrated to be specific to certain spermatogenic stages, indicating a role in germ cell development (Bremner et al., 1994). Further characterization of the stages of the tubules in models of divergent nutrition may provide insight on the interaction of nutrient levels and hormonal signals and subsequent effects on spermatogenesis.

In summary, abundance of the activated form of nutrient sensing regulator, phosphorylated mTOR, was increased in the testicular tissue of bulls on a negative plane of nutrition. This may be the result of the altered nutrient availability to the

Table 1. Optical density of fluorescent staining for mTOR, p-mTOR, ratios, and AR abundance in testicular parenchyma of bulls managed on divergent planes of nutrition

	NEG		POS		
Item	**Mean**	**SE**	**Mean**	**SE**	***P*-value**
Seminiferous Tubule					
mTOR	362.6	69.6	348.8	69.6	0.89
p-mTOR	1256.5	167.4	759.4	178.9	0.06
Ratio (p-mTOR/mTOR)	4.0	0.9	2.8	0.9	0.32
AR	2588.2	626.4	3028.2	669.7	0.64
Interstitial Space					
mTOR	107.5	14.8	111.2	14.7	0.86
p-mTOR	179.9	19.3	80.1	20.6	0.004
Ratio (p-mTOR/mTOR)	1.8	0.2	0.8	0.2	0.009
AR	896.5	144.3	1003.0	154.3	0.62

[1]Treatments were POS = bulls managed on a positive plane of nutrition over 112 d; NEG = bulls managed on a negative plane of nutrition over 112 d. AR = androgen receptor; mTOR = mammalian Target of Rapamycin; p-mTOR = phosphorylated mTOR; SE = standard error; ST = seminiferous tubule

Table 2. Number of Sertoli cells, germ cells, and ratio of germ cells to Sertoli cells in the seminiferous tubules of bulls managed on divergent planes of nutrition

	NEG		POS		
Item	**Mean**	**SE**	**Mean**	**SE**	***P*-value**
Cell Counts					
Sertoli cells / ST	21.1	1.9	21.9	2.1	0.78
Germ cells / ST	170.5	8.3	158.9	8.8	0.35
Ratio (germ cells / Sertoli cells)	9.3	0.7	8.1	0.7	0.21

[1]Treatments were POS = bulls managed on a positive plane of nutrition over 112d; NEG = bulls managed on a negative plane of nutrition over 112 d. SE = standard error; ST = seminiferous tubule

SC, in response to excess or reduction of circulating metabolites, such as amino acids. Future research will evaluate the expression of glucose and amino acid transporters in the seminiferous tubules to further elucidate the contributions of nutrition on SC function and sperm production. While there were no differences in the abundance of AR or germ cell to SC ratio, metabolic differences within the SC may have lasting effects on sperm quality, sire fertility, and epigenetic messages carried to offspring.

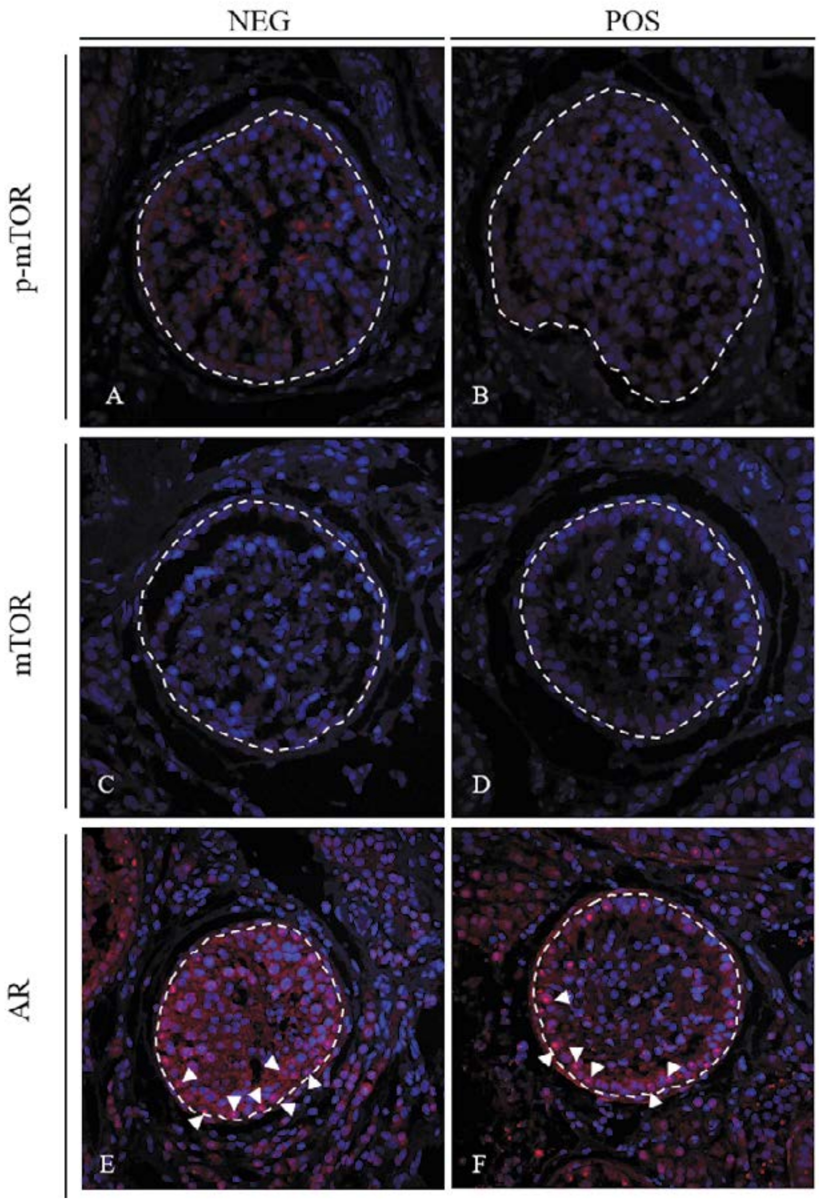

Figure 2. Immunohistochemistry staining of testicular biopsies of bulls on divergent planes of nutrition. Respective antibody staining is represented in red. DAPI staining of nuclei is represented in blue. Seminiferous tubules are outlined by the dashed white line and remaining space outside of tubule is the interstitial space. Arrowheads indicate to Sertoli cells, characterized by localized androgen receptor (AR) abundance. Fig. A & B: p-mTOR abundance in NEG and POS bulls. Fig. C & D: total mTOR in NEG and POS bulls. Fig. E & F: AR abundance in NEG and POS bulls.

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Managing mature beef bulls on divergent planes of nutrition alters scrotal circumference and concentrations of hormones and metabolites

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Plane of nutrition in mature bulls fluctuates over the course of a year due to the demands of the breeding season and as a result of strategies implemented to regain weight and prepare for the subsequent breeding season. We developed a model to evaluate the impacts of divergent planes of nutrition that resulted in bulls managed on a positive plane of nutrition having enhanced concentrations of hormones and metabolites compared with bulls managed on a negative plane of nutrition. Further investigation into the fertility and offspring outcomes resulting from our model of divergent bull nutrition are ongoing.

Summary

Fifteen mature beef bulls (4 and 5 years old; BW = 1,816 ± 38.3 lb) were used in each of two years to evaluate effects of divergent planes of nutrition on concentrations of hormones and metabolites. In Year 1, bulls were ranked by BW and randomly assigned to one of two treatments for a 112-d evaluation period; 1) managed on a positive plane of nutrition (POS), or 2) managed on a negative plane of nutrition (NEG). In Year 2 bulls were assigned to the opposite treatment they received in Year 1 (i.e. POS in Year 1 were assigned to NEG in Year 2, and vice versa). Bulls were fed a common diet with deliveries into Insentec feeders adjusted biweekly to achieve targeted weight loss or gain (~12.5% of original BW). Blood samples were collected on d 0, 56, and 112 and analyzed for concentrations of amino acids (AA) in Year 1 and for glucose, non-esterified fatty acids (NEFA), testosterone (T), triiodothyronine (T3), thyroxine (T4), and insulin-like growth factor-1 (IGF-1) in Year 1 and Year 2. By design, bull BW was influenced by a treatment × day interaction ($P < 0.001$), with POS bulls being heavier ($P < 0.01$) than NEG bulls by d 28. Over the course of the experiment POS bulls gained 2.74 ± 0.10 lb/d while NEG lost 2.35 ± 0.10 lb/d. Body condition score and scrotal circumference were also impacted by treatment × day interactions ($P < 0.001$), both starting similar among treatments, then greater for POS than NEG thereafter. To achieve targeted weight divergence POS bulls (30.4 ± 0.99 lb/d) ate more ($P < 0.0001$) than NEG bulls (11.2 ± 0.99 lb/d). Concentrations of glucose, NEFA, T3, T4, and IGF-1 were influenced by treatment × day interactions ($P < 0.001$). Concentrations of glucose, T3, T4, and IGF-1 were greater ($P < 0.01$) for POS bulls on d 112 compared with NEG bulls on the same days. Concentrations of NEFA, however, were greater ($P < 0.001$) for NEG than POS on d 56 and 112. Total amino acids present in serum were impacted by a treatment × day interaction ($P < 0.001$), with POS bulls having more ($P \leq 0.001$) AA present in serum than NEG bulls on d 56 and 112. Our model resulted in altered body composition and profiles of hormones and metabolites which could have effects on testicular tissue and semen at functional, morphological, and molecular levels. Further investigation into the fertility and offspring outcomes resulting from our model of divergent bull nutrition are ongoing.

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Introduction

Dramatic and dynamic changes in body weight and plane of nutrition occur within a year in the life of breeding bulls. Factors contributing to weight loss in mature bulls may be due to work load and nutritional management. A survey of producers revealed that stocking rates varied from 4 cows per bull up to 80 cows per bull (Dahlen and Stoltenow, 2015), and bulls can experience dramatic weight loss; between 100 and 400 lb (Walker et al., 2009; Hersom and Thrift, 2008). Bulls losing weight during the breeding season must subsequently be managed to regain lost weight (Barth 2013).

Producer decisions determine the point at which bulls begin losing and gaining weight relative to the breeding season. In some scenarios, bulls begin losing weight only at the beginning of breeding season, and are then managed to gain weight thereafter, reaching targeted optimal weight just before the subsequent breeding season. Bulls in this scenario are in a positive energy balance over the time course of spermatogenesis. In other scenarios bulls may start losing weight before the breeding season. Perhaps these bulls experienced a recent change in environment and diet after purchase, or perhaps they were managed to gain weight over winter and needed to be cut back to get into "breeding shape" or placed on pastures to graze ahead of the breeding season. In either instance, these bulls would be on a negative plane of nutrition leading up to the breeding season. When we evaluate the two respective scenarios together we see a major and common divergence in plane of nutrition leading up to the breeding season.

Spermatogenesis is a continual process that takes roughly 61 d for sperm development, followed by up to 14 d residence in the epididymis prior to ejaculation (Senger, 2012). The net result is that sperm used to inseminate a cow today likely began the process of development up to 75 d before breeding. Thus, divergence in plane of nutrition likely exposes sperm to different hormonal profiles and metabolic substrates during the time of spermatogenesis, residence in the epididymis, and upon combination with seminal plasma at ejaculation. The consequences of these differing environments remain underexplored. Therefore, our objectives were to evaluate divergent planes of nutrition on body composition and concentrations of hormones and metabolites.

Experimental Procedures

All procedures were approved by the North Dakota State Institution for Animal Care and Use Committee.

Fifteen mature beef bulls (4 and 5 years old; BW = 1,816 ± 38.3 lb) were used in each of two years to evaluate effects of divergent planes of nutrition on body composition and concentrations of hormones and metabolites. In Year 1 bulls were ranked by BW and randomly assigned to one of two treatments for a 112-d evaluation period; 1) managed on a positive plane of nutrition (POS), or 2) managed on a negative plane of nutrition (NEG). In Year 2 bulls were assigned to the opposite treatment they received in Year 1 (i.e. POS in Year 1 were assigned to NEG in Year 2, and vice versa). In each year bulls were fed a common diet containing corn silage, triticale hay, cracked corn, dried distiller's grains plus solubles, and a vitamin/mineral premix (Table 1). Diets were placed in Insentec feeders with deliveries adjusted based on biweekly body weight to achieve targeted weight loss or gain (~12.5% of original BW). Scrotal circumference and body condition score were determined every 28 days.

Blood samples were collected on d 0, 56, and 112 from the tail vein. Samples were allowed to clot for 30 minutes and centrifuged at 1,500 × g at 4 C for 20 minutes. Serum samples were separated and stored in plastic vials at -20°C until further analysis. Samples were analyzed using the Synergy H1 Microplate Reader (Biotek, Winooski, VT) with the Infinity Glucose Hexokinase Kit (Thermo Scientific, Waltham, MA) and NEFA-C Kit (WAKO Chemicals, Inc., Richmond, VA). Serum samples were analyzed for concentrations of testosterone (T), triiodothyronine (T3), thyroxine (T4), and insulin-like growth factor-1 (IGF-1) by competitive chemiluminescent immunoassay using the Immulite 1000 (Siemens, Los Angeles, Calif.). Concentrations of total amino acids were determined in serum samples from Year 1 only using the ACQUITY Ultra-Performance Liquid Chromatography System (Waters Corporation, Milford, Mass.).

Table 1. Dietary ingredients and nutrient profile of diet fed to bulls on divergent planes of nutrition

Item	Percent in diet
Ingredient, %	%, DM Basis
Corn silage	44.6
Triticale hay	27.4
Cracked corn	8.0
DDGS	15.6
Premix	4.4
Nutrient Composition	
Ash, %	9.16
Crude Protein, %	12.32
ADF, %	27.34
NDF, %	49.96
Fat, %	2.91
Ca, %	0.56
P, %	0.39

Data were analyzed using the MIXED procedures of SAS for effects of treatment, collection day, year, and their respective interactions with bull as the experimental unit. Differences were considered significant at a $P \leq 0.05$.

Results and Discussion

By design, BW of bulls on the respective treatments diverged over the course of the experiment. Bulls on the POS treatment tended ($P = 0.08$) to be heavier than NEG bulls by d 14 of the experiment, with differences significant by d 28 ($P < 0.01$; Figure 1, Panel A) and continuing through the evaluation period. Over the course of the experiment POS bulls gained 2.74 ± 0.10 lb/d while NEG lost 2.35 ± 0.10 lb/d. To achieve targeted weight divergence POS bulls (30.4 ± 0.99 lb/d) ate more ($P < 0.000$) than NEG bulls (11.2 ± 0.99 lb/d).

Body condition score was also impacted by a treatment × day interaction ($P < 0.001$), with BCS starting similar among treatments, then being greater ($P < 0.01$) for POS than NEG from d 28 to 112 (Figure 1, Panel B). By the end of the evaluation period there was a 2.3 BCS unit difference between treatments. Additionally, scrotal circumference was impacted by a treatment × day interaction ($P < 0.001$), with no difference present at the beginning of the experiment, but divergence between treatments beginning on d 56 and continuing through the end of the evaluation period (Figure 1, Panel C).

Concentrations of glucose, NEFA, T3, T4, and IGF-1 were influenced by treatment × time interactions ($P < 0.001$; Table 2). Concentrations of glucose, T3, T4, and IGF-1 were greater ($P < 0.01$) for POS bulls on d 112 compared with NEG bulls on the same days. However, concentrations of NEFA were greater ($P < 0.001$) for NEG than POS on d 56 and 112. Concentrations of testosterone evaluated from a single blood sample before feeding were not impacted by the treatment × day interaction ($P = 0.44$) or by the main effect of treatment ($P = 0.40$). Concentrations of testosterone did increase ($P < 0.001$) through the evaluation period as days lengthened and the traditional breeding season approached. As testosterone is released episodically from Leydig cells in respond to pulses of LH from the pituitary, future work should include serial sampling or GnRH challenges to more precisely evaluate the impact of bull nutrition on concentrations of testosterone.

Total amino acids present in serum were impacted by a treatment × day interaction ($P < 0.001$), with POS bulls having more ($P \leq 0.001$) AA present in serum than NEG bulls on d 56 and 112 of the evaluation period (Figure 2).

Under the common production scenarios evaluated in this experiment, fluctuations in body weight and plane of nutrition of breeding bulls lead to changes in blood hormone and metabolite profiles. Increased hormone and metabolite concentrations in POS bulls were a product of enhanced plane of nutrition, and elevated NEFA in NEG bulls was indicative of bulls mobi-

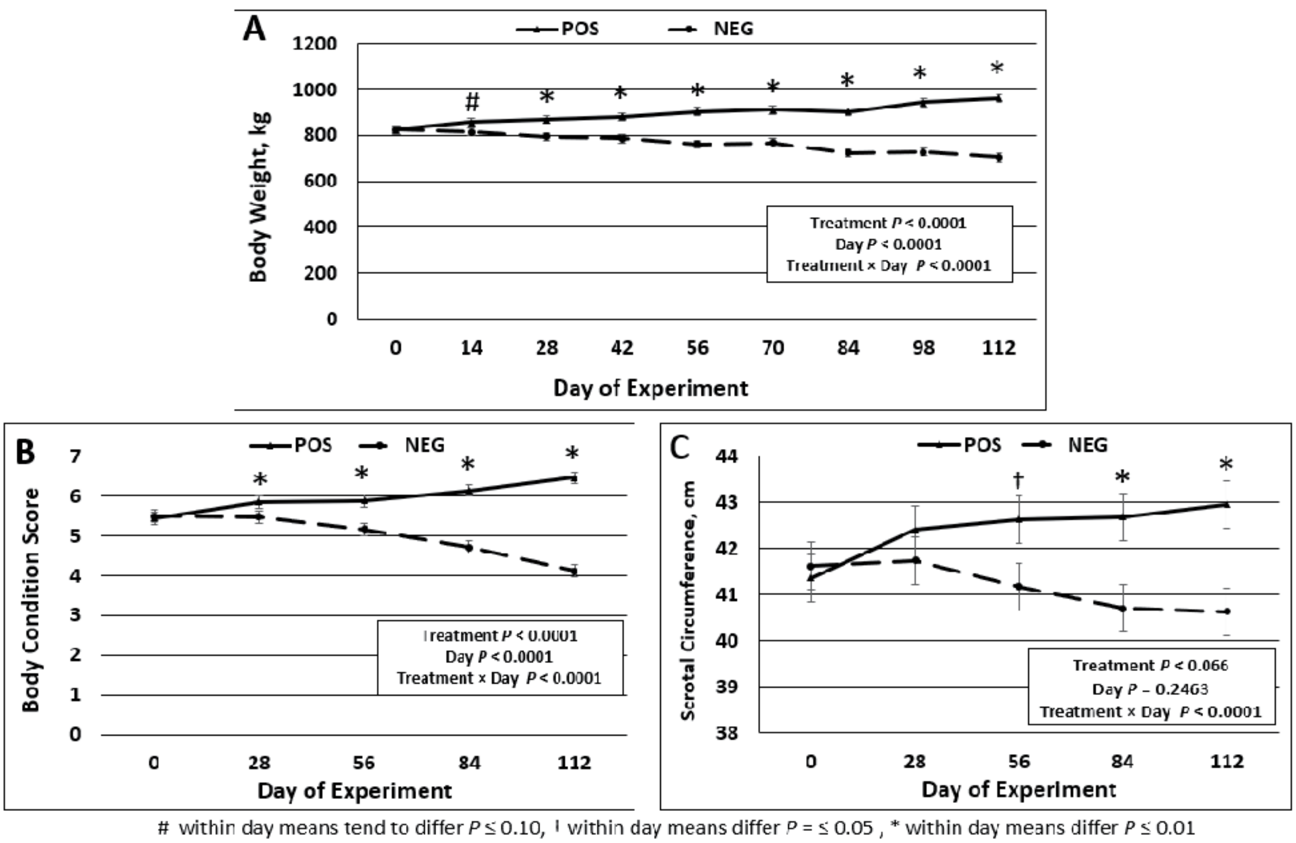

Figure 1. Body weight (Panel A), body condition score (Panel B), and scrotal circumference (Panel C) of beef bulls managed on divergent planes of nutrition. Bulls on POS were targeted to gain 12.5% of BW over 112 d, whereas bulls on NEG were targeted to lose 12.5% of initial BW over 112 d. # within day means tend to differ P ≤ 0.10; † within day means differ P = ≤ 0.05; * within day means differ P ≤ 0.01.

Table 2. Effects of divergent planes of nutrition on serum concentrations of hormones and metabolites in mature beef bulls

	Treatment[1]									
	NEG			POS				*P*-Values		
Collection day	0	56	112	0	56	112	SE	TRT	Time	TRT × Time
Glucose, mg/dl	74.7^{xy}	63.2^{z}	65.2^{z}	70.2^{y}	72.0^{xy}	75.6^{x}	1.812	0.01	0.012	<0.001
NEFA, µmol/L	309.7^{y}	810.9^{x}	816.5^{x}	254.8^{y}	148.0^{z}	211.1^{yz}	42.36	<0.001	<0.001	<0.001
Testosterone, ng/dl	1358	1750	3485	1423	3109	4427	772	0.40	<0.001	0.44
T3, ng/dl	98.2^{x}	56.9^{y}	50.8^{y}	93.0^{x}	64.3^{y}	104.7^{x}	9.11	0.12	<0.001	<0.001
T4, µg/dl	6.53^{x}	4.08^{y}	3.99^{y}	5.81^{x}	4.40^{y}	5.80^{x}	0.293	0.21	<0.001	<0.001
IGF-1	282.9^{x}	190.8^{y}	162.4^{z}	277.1^{x}	295.8^{x}	291.3^{x}	17.06	0.002	<0.001	<0.001

[1]Bulls on POS were targeted to gain 12.5% of BW over 112 d, whereas bulls on NEG were targeted to lose 12.5% of initial BW over 112 d.
^{x,y,z}Means within row lacking common superscript differ ($P \leq 0.05$).

lizing body reserves and a source of energy. The observed alterations in blood profiles likely resulted in alterations of nutrients available for developing sperm. Whether and how these different blood nutrient profiles influenced cellular function in the testis and in sperm produced should be further evaluated. Specific efforts being undertaken with our model of divergent planes of nutrition include evaluating novel measures of fertility via flow cytometry, evaluating the mRNA and miRNA of resultant sperm, and evaluating *in vitro* fertility and embryo development, with the ultimate goal of evaluating offspring outcomes.

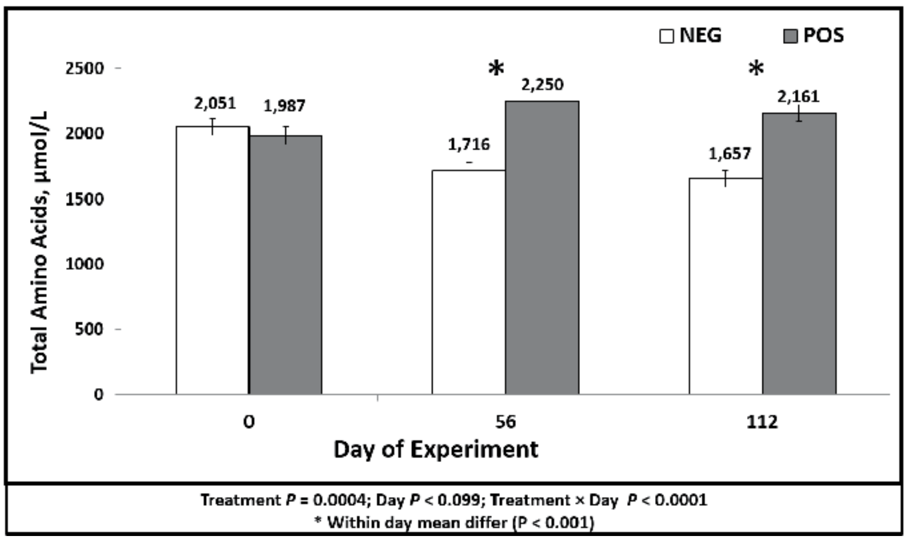

Figure 2. Total amino acids present in serum of bulls managed on divergent planes of nutrition. Bulls on POS were targeted to gain 12.5% of BW over 112 d, whereas bulls on NEG were targeted to lose 12.5% of initial BW over 112 d. * within day means differ P ≤ 0.01.

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A comparison of meat quality and sensory attributes in fresh and frozen American lamb using two different muscles

Michaella A. Fevold[1], Kasey R. Maddock-Carlin[1] and Travis W. Hoffman[1]

The objective of this study was to evaluate differences in meat quality and sensory attributes of fresh and frozen lamb in the longissimus lumborum (LL) and semimembranosus (SM) muscles. While quality and sensory attributes of the SM were not affected by freezing, quality and sensory attributes such as water loss and perceived juiciness and tenderness of the LL were negatively affected as seen by increased water loss and decreased tenderness and juiciness-like scores in consumer sensory panels.

Summary

NDSU-raised lambs (n = 12) were slaughtered at the NDSU Meats Laboratory. After a 24-hour chill, loin and leg subprimals were collected from each carcass and assigned to either fresh (FRSH) or frozen (FRZN) treatment. Meat quality and sensory tests were performed on each sample. Consumer panelists (n = 84) were given paired samples of LL and SM and were asked to evaluate overall like, flavor, tenderness and juiciness on a continuous line scale. No differences were observed ($P \geq 0.10$) between treatments for primal weight loss, cook loss or Warner-Bratzler shear force in either the LL or SM. However, LL and SM samples in the FRSH treatment had less drip loss compared with samples in the FRZN treatment ($P = <0.001$). In LL, sensory samples in the FRSH treatment had greater ($P = 0.01$, $P = 0.02$, $P = 0.03$, respectively) overall like, tenderness and juiciness scores compared with samples in the FRZN treatment. However, no differences in flavor scores were observed in LL sensory samples in the FRSH treatment compared with samples in the FRZN treatment. Additionally, no differences in overall like, flavor, tenderness or juiciness scores were observed ($P \geq 0.77$) in SM sensory samples in the FRSH treatment compared with samples in the FRZN treatment. Results indicate retailers may use frozen storage on lamb legs, however, consumers do discriminate against loin chops treated to frozen storage due to water loss and perceived tenderness issues.

Introduction

A common challenge in the U.S. lamb industry is inconsistencies in the supply of fresh lamb related to lambing time and rates in the traditional U.S. lamb system, with about 80% of the U.S. lamb crop being born in the first five months of the year (Redden et al., 2018). The use of frozen lamb could resolve some of these issues during spikes in lamb demand around the Christmas and Easter holidays. However, retailers often discriminate against frozen lamb in the retail case.

Some research has been performed on meat quality and sensory attributes of frozen lamb. However, conclusions are inconsistent on whether frozen lamb is a viable option for U.S. retailers (Smith et al., 1968; Muela et al., 2016). Therefore, additional research is needed to understand how freezing affects meat quality and sensory attributes of American lamb to provide better research-based guidance to retailers and food service on the consumer perceptions of frozen lamb and whether frozen lamb is a viable option for U.S. consumers.

Experimental Procedures

NDSU-raised lambs (n = 12) were slaughtered at the NDSU Meats Laboratory. After a 24-hour chill, loin and leg subprimals were collected from each carcass. Subprimals were split in half and each side was assigned to either fresh (FRSH) or frozen (FRZN) treatment. Each half was weighed before being vacuum sealed.

Subprimals assigned to the FRSH treatment were stored in a cooler at 3 C for 14 days while subprimals assigned to the FRZN treatment were stored in a freezer for 13 days at 3 C + one day of thawing. Before fabrication, subprimals were removed from bags and reweighed for primal weight loss. After weighing, loin subprimals were fabricated starting at the cranial end, while the SM was removed from the leg subprimal and fabrication began at the distal end.

For both muscles, an approximately 1.27-centimeter (cm) chop was removed for drip loss analysis, an approximately 2.54-cm chop was fabricated, vacuum-sealed and stored at 3 C for Warner-Bratzler shear force (WBSF) and cook loss evaluation, and the remaining chop samples were used for sensory evaluation. Drip loss was determined during a 24-hour period from suspended 25-gram (g) samples. Warner-Bratzler shear force and cook loss analysis was conducted in accordance with American Meat Science Association guidelines.

Sensory evaluation was conducted 24 hours after sample

1Animal Sciences Department, NDSU

fabrication. Consumer panelists (n = 84) were given paired samples of LL and SM and were asked to evaluate overall like, flavor, tenderness and juiciness on a continuous line scale. Data were analyzed using the PROC Mixed procedure SAS Studio® (SAS Institute, Cary, N.C.) with means being separated with the PDIFF option and were considered significant when $P \leq 0.05$.

Results and Discussion

No differences were observed between treatments for primal weight loss, cook loss or WBSF in the LL or SM ($P \geq 0.10$; Table 1). However, LL and SM samples in the FRSH treatment had ($P = 0.01$, $P = 0.02$, $P = 0.03$, respectively; Table 2) less drip loss compared with samples in the FRZN treatment ($P = <0.001$; Table 1).

Sensory samples in the FRSH treatment had greater overall like, tenderness and juiciness scores compared with samples in the FRZN treatment. However, no differences in flavor scores were observed in LL sensory samples in the FRSH treatment compared with samples in the FRZN treatment. Additionally, no differences ($P \geq 0.77$; Table 2) in overall like, flavor, tenderness or juiciness scores were observed in SM sensory samples in the FRSH treatment compared with samples in the FRZN treatment.

Our results indicate minimal influence on meat quality and sensory attributes of SM in lamb when frozen. Industry application of frozen storage may be beneficial for supply of legs. However, we did identify negative influences on sensory attributes to lamb LL by freezing, specifically related to water-holding capacity and juiciness.

Overall consumer like differences are attributed to the perceived juiciness and tenderness, while flavor profiles of fresh vs. frozen lamb were indistinguishable. Therefore, maintaining fresh lamb loin chops in retail and food service offers the greatest opportunity for consumer satisfaction. However, further research is warranted due to the short freezing time of samples in this project.

Acknowledgments

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Table 1. Least squares means of the effect of fresh and frozen storage of American lamb on subprimal weight loss, drip loss, cook loss and shear force values on longissimus lumborum and semimembranosus chops

	Storage Conditions			
	Fresh	Frozen	SEM	*P*-value
Longissimus lumborum				
n	12	12		
Subprimal weight loss, %	0.867	1.608	0.441	0.12
Drip loss, %	0.850^{a}	4.800^{b}	0.451	< 0.001
Cook loss, %	17.5	17.6	1.4	0.96
WBSF, kg	2.88	3.21	0.30	0.30
Semimembranosus				
n	12	10		
Subprimal weight loss, %	0.283	0.575	0.161	0.10
Drip loss, %	2.30a^{a}	6.67^{b}	0.77	<0.001
Cook loss, %	19.1	21.2	1.9	0.30
WBSF, kg	3.19	3.39	0.28	0.49

^{a,b}Means in same row without common superscript differ ($P < 0.05$).

Table 2. Least squares means of the effect of fresh and frozen storage of American lamb on consumer sensory attribute scores on a 0 to 100 continuous scale[1] of longissimus lumborum and semimembranosus chops.

	Storage Conditions			
	Fresh	Frozen	SEM	*P*-value
Longissimus lumborum				
n	12	12		
Overall like	64^{a}	56^{b}	2.9	0.01
Flavor like	64	59	3.2	0.14
Tenderness like	62^{a}	55^{b}	2.8	0.01
Juiciness like	59^{a}	52^{b}	2.7	0.03
Semimembranosus				
n	12	12		
Overall like	58	57	3.9	0.85
Flavor like	60	60	3.0	0.92
Tenderness like	54	54	3.9	0.99
Juiciness like	52	53	4.0	0.77

[1]0 = greatest disliking, 100 = greatest liking

^{a,b}Means in same row without common superscript differ ($P < 0.05$).

Horse management webinar series: Expanding NDSU Extension's reach to equine enthusiasts

Mary Keena[1]

This report describes the development of the Extension horse management webinar series. Survey results suggest that the webinars were utilized by many constituents and that the constituents found the webinars useful and utilized the information to make improvements on their horse operations.

Introduction

The 2012 North Dakota horse inventory was 45,271. This is the last time horse data was gathered by the National Agricultural Statistics Service. Based on positive feedback from 2016 horse meetings, combined with current requests NDSU Extension agents were receiving, we determined that hosting horse management-related programming was necessary and relevant for our constituents. This report describes the development of the horse management webinar series.

Extension Response

Initial plans were to host educational meetings in four to five counties across North Dakota with a high concentration of horses. When COVID-19 restrictions were implemented, meetings moved to an online format.

Based on a needs assessment, we learned that most North Dakota horse owners work during the day in nonhorse-related careers, so a live, noon webinar series was created and recorded for later viewing. Four spring-related webinars and two winter-related webinars were held during the 2020 reporting year. Topic areas were picked based on feedback gathered during each webinar.

Two hundred fifty-two unique individual registered for the webinar series, with 66% being from North Dakota and 13% from Minnesota. We also hosted international participants from Australia, Canada, France, Germany and Peru. Eighty-three percent of the participants who joined sessions in real time were horse owners or stable owners/managers.

Results and Discussion

Ninety-eight percent of the participants who joined sessions in real time said the webinars were useful or extremely useful. The webinar videos were watched in real time or viewed via the recording a total of 914 times.

In a six-month survey that was sent to the spring webinar registrants, they indicated management changes were made because of the webinar information.

The following comments are from participants who made changes within six months of the spring webinar series:

- "I changed my pasture size, rotation schedule and let one overgrazed area rest for the year."
- "Helped my landlord with some composting tips with the manure piles from previous renters who had horses. Changed up my parasite control to help reduce resistance and also more frequently with the summer parasite concentrations we had."
- "Bought a manure spreader."

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Leigh Ann Skurupey
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NDSU Non-Extension Collaborators:
Carrie Hammer

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Intersection of the Cattle and Beef Industries

Lisa Pederson[1]

The COVID-19 pandemic was disrupting to the U.S. beef industry. Marketing, processing and distribution channels were interrupted in a manner never seen before. NDSU Extension created a series of webinars to provide accurate science- and evidence-based information that allowed producers, consumers and decision makers to make more informed decisions in the face of chaos. Only by understanding the entire breadth of the cattle and beef industries can we comprehend the impacts of major industry disruptions such as the COVID-19 pandemic or packing plant fires.

Introduction

The beef industry as a whole was challenged as COVID-19 disrupted the marketing, harvest, processing and distribution of livestock and their products. This series of programs was designed to give perspective to the situation created by the closing of harvest facilities as well as look at how COVID had disrupted the normal production cycle of beef. Due to the confusion and chaos surrounding this disruption, our objective with this webinar series was to provide an accurate, science- and evidence-based overview of the U.S. beef industry from conception to consumption for cattle producers, consumers and decision makers.

Extension Response

Collaborators from North Dakota State University Extension, Texas A&M Agrilife Extension and West Virginia University Davis College of Agriculture assembled experts from all facets of the beef industry continuum to present scientific and evidence-based information in a 15-session webinar series. Beginning on May 7, 2020, twice weekly webinars covered the following topics: overview of the current situation; imports, exports and MCOOL; packer profits; the pork and poultry industries, how the beef industry is similar and different; local meats: challenges and opportunities; the Beef Checkoff; in-depth perspective of how cattle are priced: a discussion about price and value discovery, and the futures market; virtual packing plant tour; ground beef, heavy carcasses and imports; domestic and international supply and demand; historical overview of the beef industry; changes in how beef is supplied to consumers in grocery stores and restaurants; in-depth perspective of drop credit, hide and offal; an in-depth look at market cows: trading in cows, upgrading cows and improving your cowherd; the intersection of the cattle and beef industries: change is inevitable, progress is optional. Has improvement in carcass merit and growth equaled progress in the cow herd?

Results and Discussion

The webinar series had more than 3,000 in-person participants from eight countries and the recordings have had more than 400 views. Participant survey data demonstrated that 90% of attendees agreed or strongly agreed that they learned what they expected (Figure 1).

Surveys also indicated that producer knowledge significantly increased from prior to attending webinars to after receiving education. Before programming, 17% of attendees rated their topic knowledge as "a lot" or a "great deal," and

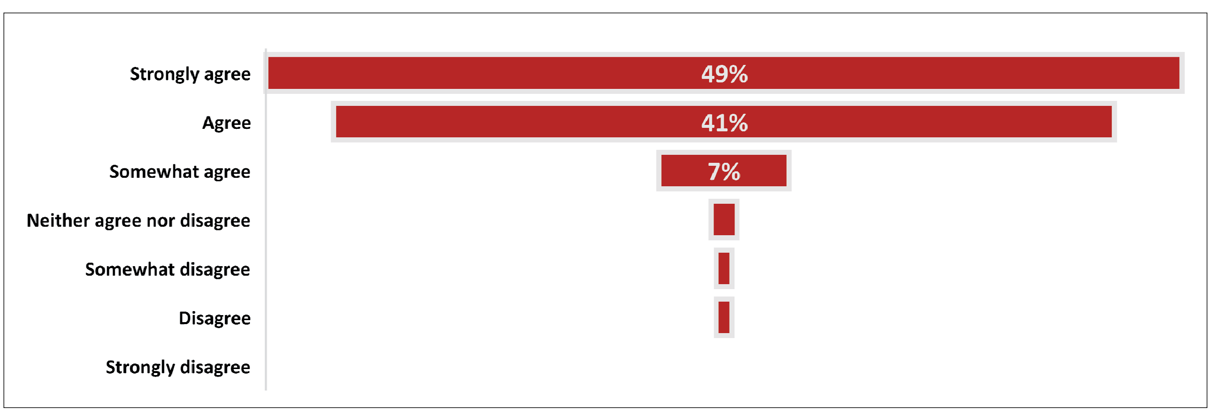

Figure 1. Intersection of the Cattle and Beef Industries. Did you learn what you expected? Participant data from 15 sessions.

[1]Central Grasslands Research Extension Center, NDSU

after the webinar sessions, 81% of attendees rated their knowledge as "a lot" or a "great deal" (Figure 2). Attendees reported using the information taught on the webinars to make more educated business and policy decisions and several who were members of state legislatures stated they used the information to be more informed when developing or deciding on legislation impacting the beef industry.

The webinar series is archived for future viewing at www.ag.ndsu.edu/livestockextension/intersectionwebinars.

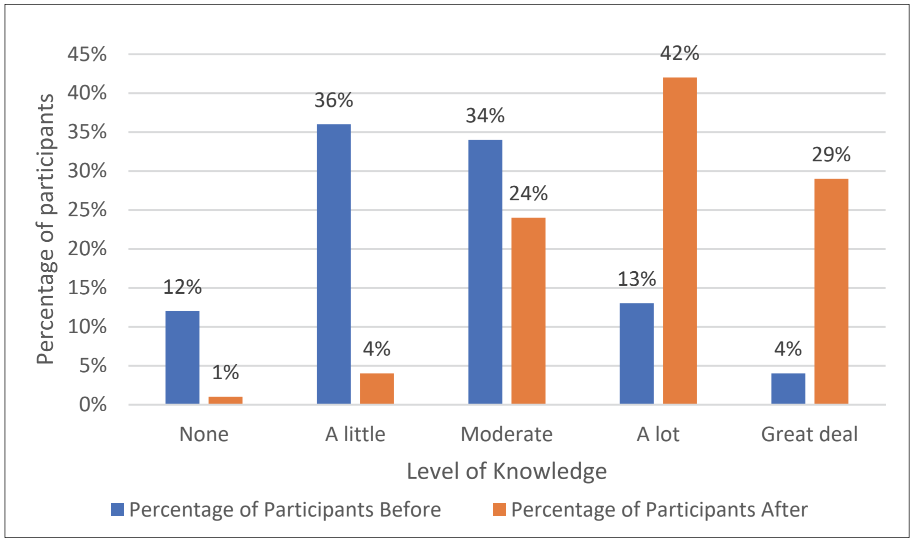

Figure 2. Participant Knowledge Before and After Attending Intersection of the Cattle and Beef Industries

Feedback on the webinar series:

- "I don't know if you could do a greater service to the industry and the subject than these webinars. Thank you so much."
- "Never have I ever participated in such a comprehensive, 360° view of the beef and cattle industry. While being involved in many facets of beef cattle production, my eyes were opened to the many components, features, qualities and obstacles that brings beef from pasture to plate. I have shared the processes, facts and knowledge I have learned with other industry individuals, and have suggested to many young adults the time invested into this webinar is worth its weight in gold as they get a foothold on their place in this industry's future!"
- "I was fortunate to attend most of the webinars in the Intersection of Cattle and Beef series. Following are my observations related to the utility of this series for U.S. beef producers:
- The series was very timely. The U.S. beef industry had experienced two black swan events in less than eight months – The Tyson beef plant fire in August 2019 and the COVID pandemic. Both impacted the beef industry by disrupting the harvest and distribution of beef. This disruption immediately impacted cattle prices and compromised the profitability/sustainability of many operations.
- The webinar series was informative, especially for cow-calf producers and those lacking experience in the feeding, harvesting and distribution segments of the beef industry. Participants were allowed virtual 'behind the scenes' visits to harvest facilities and visits with those in the business of distributing and merchandizing beef. The better one understands the entire industry, the more effective they become at managing their segment and the product(s) there from.
- By increasing knowledge and understanding of other segments of the industry, the webinar series relieved some of the distrust cow-calf felt for other segments of the industry. Record large packer margins frequented industry news outlets, while profit margins in all other segments of the industry shrunk or went negative. The webinar series masterfully explained profit margins and contributors to the magnitude of these margins."
- "As a state legislator, I used the information on the mandatory price reporting, formula pricing and price discovery. This webinar gave me a better understanding of what all was included and meant by the 30/14 50/14. It allows me to better make a decision on it!"
- "This course should be mandatory for every college student enrolled in agriculture."
- "I can hardly stand the wait for Tuesday and Thursday nights now! I know this is for producers but consumers can learn a lot too! - retired electrical engineer with zero agricultural experience except eating food from Texas"

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Davvy Griffin, PhD, Texas A&M Agrilife Extension
Jerry Yates, Davis College of Agriculture, West Virginia University

NDSU Extension assesses quality of livestock water sources impacted by drought

Miranda A. Meehan[1]

Providing adequate water to livestock is critical for animal health and production. The goal of this Extension program is to improve the quality of livestock water and reduce losses of livestock due to toxic water conditions during drought. To date, 740 samples have been screened. They displayed high variability in the total dissolved solids (TDS) and sulfate concentrations of the samples, reinforcing the importance of monitoring water quality of water sources. Surface water sources have greater potential to have elevated TDS and sulfate concentrations in comparison with groundwater.

Summary

Extension agents are monitoring the quality of water sources utilized by livestock that may be impacted by widespread drought. To date, Extension agents have screened 740 water samples from 588 locations in 37 counties. Samples were classified based on county, sample date and water source. The TDS and sulfate were screened using an electric conductivity meter and sulfate test strips, respectively. Samples screened displayed high variability in the TDS concentration, ranging from 125 to 16,640 parts per million (ppm,) and sulfates, ranging from less than 200 to 11,626 ppm. The majority of the samples screened were acceptable for livestock consumption, with TDS concentrations below 3,000 ppm (84%) and sulfate levels below 800 ppm (73%). Surface water sources had a greater potential to have elevated TDS concentrations, with 17% of samples exceeding 3,000 ppm, in comparison with only 4% of groundwater samples. A similar trend was observed for sulfates, with 32% of surface water and 18% of groundwater samples exceeding 800 ppm. The variation in the results to date reinforces the importance of monitoring water quality of water sources throughout the grazing season to ensure livestock performance and health are not negatively impacted by water quality.

Introduction

Providing adequate water to livestock is critical for animal health and production. Good-quality water can increase your cattle's feed intake and weight gain. The quality of water accessible to livestock is directly tied to the amount of forage they consume.

Gains can be improved by as much as 0.24 pound per day in yearlings and 0.33 pound per day in calves receiving good-quality water. Providing good-quality water also can improve herd health. Livestock whose primary water sources are ponds and dugouts have a greater risk of contracting illnesses such as giardia, leptospirosis and cyanobacterial poisoning, compared with livestock drinking from a trough.

All natural water contains salts, which are dissolved minerals or solids. Elevated concentrations of TDS and sulfates can be toxic to livestock. The concentration of TDS and sulfates is measured in ppm.

Water quality varies depending on the source. When runoff is low in the spring or during a drought, the salts in surface water become more concentrated as water concentrations decline, and can reach concentrations that are toxic. Groundwater tends to be of higher quality than surface water; however, some aquifers in North Dakota have naturally high concentrations of potentially toxic salts, such as sulfate, due to geology.

In response to statewide drought conditions, NDSU Extension is screening the quality of livestock water sources to reduce losses of livestock due to toxic water conditions. NDSU Extension agents are screening the concentration of TDS and sulfates across North Dakota throughout the grazing season.

Experimental Procedures

In response to statewide drought, NDSU Extension is screening the quality of water sources utilized by livestock. To date, TDS and sulfates have been measured at 703 locations in 37 counties. Sites sampled included 98 surface water sources and 29 groundwater sources. Samples will be screened throughout the grazing season from March through October 2021. Extension agents were critical to the success of this effort, with 31 agents screening samples to date.

Water samples were screened for TDS and sulfate using an electric conductivity meter and sulfate test strips, respectively. Samples were classified based on county, sample date and water source. If

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TDS concentrations were equal to or more than 4,500 ppm or sulfates were greater than 800 at the time of screening, laboratory analysis was recommended. In addition to screening for TDS and sulfates, a visual assessment was conducted for the presence of cyanobacteria blooms.

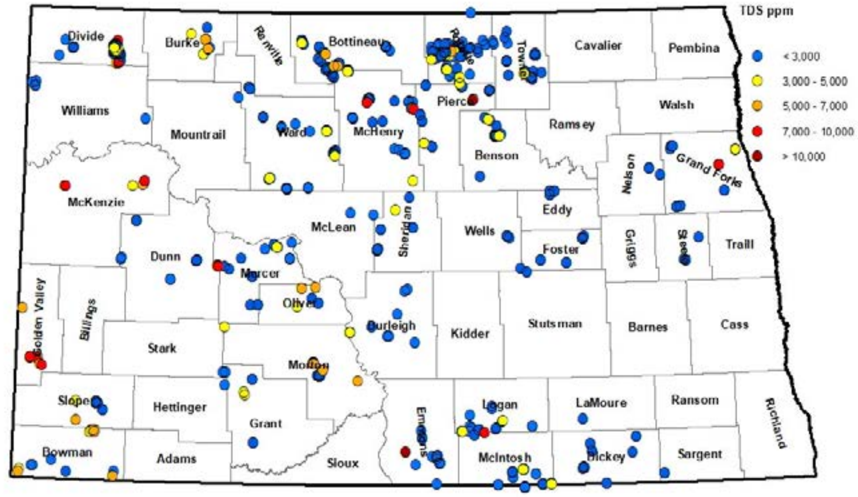

Figure 1. Total dissolved solids (TDS) in ppm of water sources screened in 2021.

Results and Discussion

To date, 740 samples have been screened for TDS and samples displayed high variability ranging from 125 to 16,640 ppm (Table 1, Figure 1). The majority of the samples screened (624, 84%) are acceptable for livestock consumptions, with TDS concentrations below 3,000 ppm. At TDS concentrations between 3,000 and 5,000, feed conversion and intake can decline thus reducing livestock performance.

Table 1. Total dissolved solid concentrations of water samples.

Total Dissolved Solids (TDS) in ppm	Groundwater	Surface Water
< 3,000	72	552
3,000 – 5,000	3	65
5,000 – 7,000		30
7,000 – 10,000		14
> 10,000		4

The TDS of 19 samples were between 3,000 and 5,000 ppm. Concentrations of TDS between 5,000 and 7,000 ppm were reported for one sample, and water with this concentration of TDS tends to have a laxative effect. Pregnant or lactating ruminants should not consume water with TDS between 7,000 and 10,000 ppm, and three samples fell in this range.

Concentrations of TDS exceeding 10,000 ppm consumption can result in brain damage or death, and three sample exceeded 10,000 ppm. Of the samples collected, 48 exceeded 5,000 ppm and were recommended to be sent to a laboratory for additional analyses.

To date, 671 samples have been screened for sulfates and samples displayed high variability ranging from less than 200 to 11,626 ppm (Table 2, Figure 2). Negative impacts to livestock health can occur when concentrations exceed 1,000 ppm for mature animals and 500 ppm for calves. Concentrations above 2,000 ppm in forage-based diets and 600 ppm in high-concentrate diets (equal to or greater than 85%) pose a risk of central nervous system disorders and death. Of the samples collected, 182 exceeded 800 ppm and were recommended to be sent to a laboratory for additional analysis.

Table 2. Sulfate concentrations of water samples.

Sulfates in ppm	Groundwater	Surface Water
< 200	42	269
> 400	12	146
> 800	9	90
> 1,200	3	31
> 1,600		50
> 2,000		20

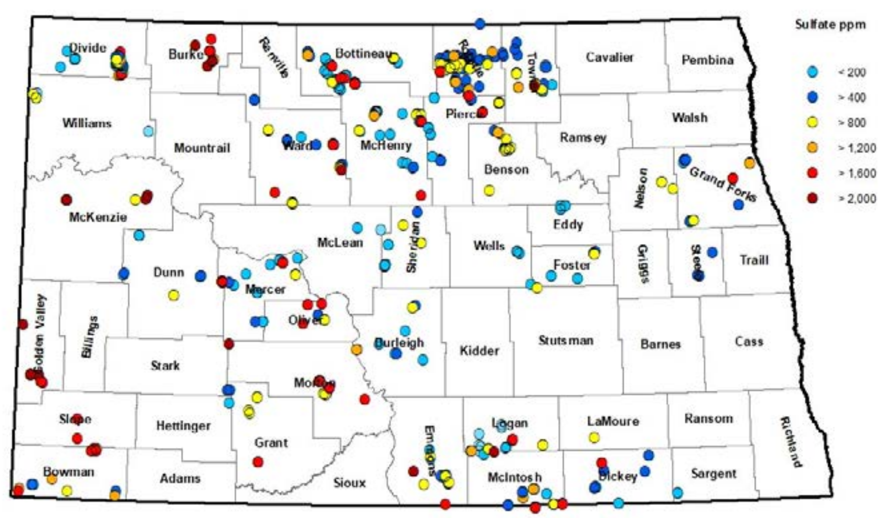

Figure 2. Sulfates in ppm of water sources screened in 2021.

Variability was observed between and within groundwater and surface water sources. Overall, groundwater had less variability and was higher quality than surface water sources (Figures 3 and 4). The average TDS and sulfate concentrations of groundwater sources was 1,315 ppm and 361 ppm, respectively. The majority (85%) of groundwater samples screened were acceptable for livestock consumption.

The TDS of surface water varied in quality ranging from 125 to 16,640 ppm, with an average of 2,074 ppm. The sulfate concentration of surface water varied in quality ranging from 100 to 11,626 ppm, with an average of 748 ppm. The TDS concentration was considered acceptable for 83% and the sulfate concentration was considered acceptable for 68% of surface water samples.

To understand the variation in water quality during the grazing season, samples were divided by month (Figures 1 and 2). Typically, TDS and sulfates tend to increase in surface waters as the grazing season progresses because of increased evapotranspiration rates in the summer months. However, fall drought and low spring runoff can influence this trend. In addition, waters with extremely high TDS and sulfates documented in March and April were not monitored in May and June because livestock no longer were allowed to access these sources.

Water quality screening and analysis of livestock sources allows ranchers to ensure water quality is not impacting livestock performance and/or health. It also can aid in making management decisions such as when livestock should be removed from a pasture or when an alternative water source should be used or developed. Installing a water development plan can help ensure that livestock have access to good-quality water throughout the grazing season and increase a ranch's drought resilience.

Results of these screenings will help us understand and demonstrate the variability in water quality and factors that may influence variability, including location, source and climate. The variation in the results to date reinforces the importance of monitoring the quality of water sources throughout the grazing season to ensure livestock performance and health are not impacted by water quality. If you are concerned about water quality, contact your local NDSU Extension agent and that person can conduct a screening and/or assist with sample collection and submission for laboratory analyses.

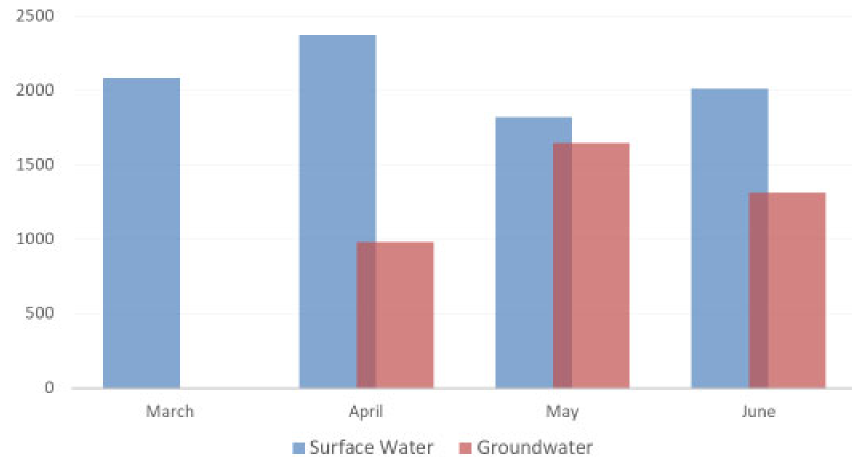

Figure 3. Average total dissolved solids (TDS) in ppm of water sources by month in 2021.

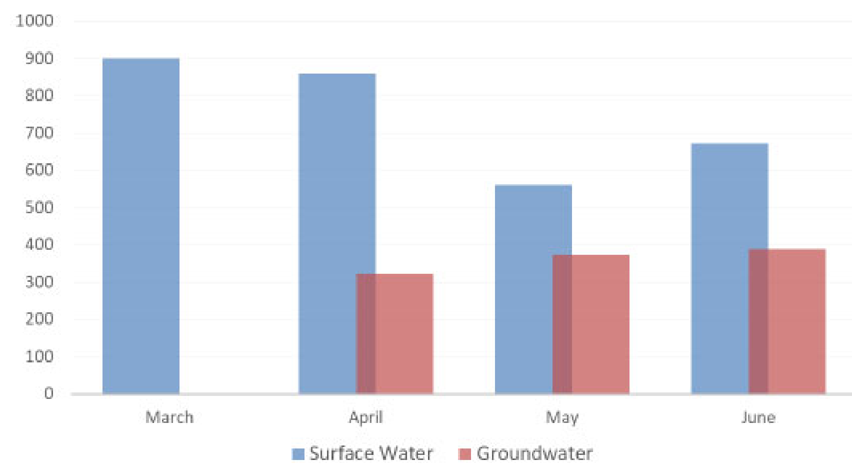

Figure 4. Average sulfates in ppm of water sources by month in 2021.

Acknowledgments

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NDSU Extension hosts webinars to help ranchers navigate drought

Miranda A. Meehan[1], Mary A. Keena[2] and Kevin K. Sedivec[3,4]

To aid ranchers in developing drought plans and navigate the ongoing drought, NDSU Extension specialists have been hosting webinars. The drought webinars hosted by NDSU Extension have provided timely information to aid ranchers in the development of drought management plans and strategies for their ranches.

Summary

Currently, 100% of North Dakota is experiencing some level of drought. The drought started in the fall of 2020, with many parts of the state experiencing one of the driest years on record. To aid ranchers in developing drought plans and navigate the ongoing drought, NDSU Extension specialists have been hosting webinars. The drought webinars hosted by NDSU Extension have provided timely information that increased participants' knowledge of drought management strategies and assisted ranchers in the development of drought management plans and strategies for their ranches.

Introduction

All of North Dakota is experiencing some level of drought. The drought started in the fall of 2020, with many parts of the state experiencing one of the driest years on record.

Extreme drought (D3) and exceptional drought (D4) classifications were assigned by the U.S. Drought Monitor on March 18 and May 20, respectively. This is the earliest these classifications have been assigned during the growing season since the inception of the U.S. Drought Monitor in 2000.

Having a plan in place, with well-defined trigger dates for implementing drought management strategies, helps ranchers endure the drought and minimize losses. The longer that ranchers wait to make management decisions, the fewer options are available and they face a greater risk of overgrazing, reduced livestock performance, the need to sell or cull more animals and greater economic losses. The objectives of the drought webinars hosted by NDSU Extension were to provide information on drought management strategies and assist ranchers in the development of drought management plans and strategies for their ranches.

Procedures

In February 2021, NDSU Extension initiated a webinar series focused on preparing a ranch for drought. This series consisted of six sessions. The topics included were: drought trigger dates, grazing strategies, supplemental feed options, livestock water, herd management and managing stress during drought. The series was broadcast live to 140 people from four countries and 15 states, while the video has been viewed 1,236 times

Due to ongoing drought conditions, NDSU Extension launched a monthly webinar series in May 2021. This webinar provides ranchers and land managers with drought outlooks and potential management strategies to consider as the drought progresses. To date, this series has been broadcast live to 45 people from three countries and seven states/provinces. In addition, the videos have been viewed 536 times.

Registration and polls were used to assess characteristics of the audience, intent to make changes and the potential impact of the webinars. In addition, data were collected to determine if changes were made by individuals who attended the planning series and registered for the navigating drought series.

Results and Discussion

The audience for both webinar series consisted of a broad range of attendees who included producers, Extension personnel and personnel from government agencies. Overall, participants indicated that the "Preparing for Drought" series increased their knowledge of the topics covered (Figure 1). The survey indicated that a total of 53 unique participants intended to make managements changes impacting more than 36,000 acres of grazing land and 6,000 head of livestock.

To date, 104 individuals have registered for the Navigating Drought on Your Ranch webinars, of which 28 attended the Preparing Your Ranch for Drought Series. During the planning series, seven (25%)

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of these individuals indicated they had a drought plan. Following the series, 8 (29%) additional participants implemented a drought plan (Figure 2).

Currently, 100% of participants in the Navigating Drought on Your Ranch webinars have indicated that the webinars have increased their knowledge of the topics covered. In addition, eight unique participants intended to make changes impacting more than 30,570 acres of grazing land and 2,430 head of livestock.

The drought webinars hosted by NDSU Extension have provided timely information to aid ranchers in the development of drought management plans and strategies for their ranches. The recordings from these webinars are available at https://youtube.com/playlist?list=PLnn8HanJ32l5O6GSBv5b2sdweInbmcn5T.

Acknowledgments

Thank you to all those who have presented or been panelists for these webinars, including Adnan Akyuz, Karl Hoppe, Nathan Spickler, Gerald Stokka, Janna Block, Lisa Pederson, Travis Hoffman, Sean Brotherson, Andrea Bowman, Charles Stoltenow, Philip Estepp, Becky Kopp-Dunham, Lilah Krebs, Zac Carlson, Ron Haugen and Tim Petry. Thank you to Linda Schuster and Scott Swanson for their technical support.

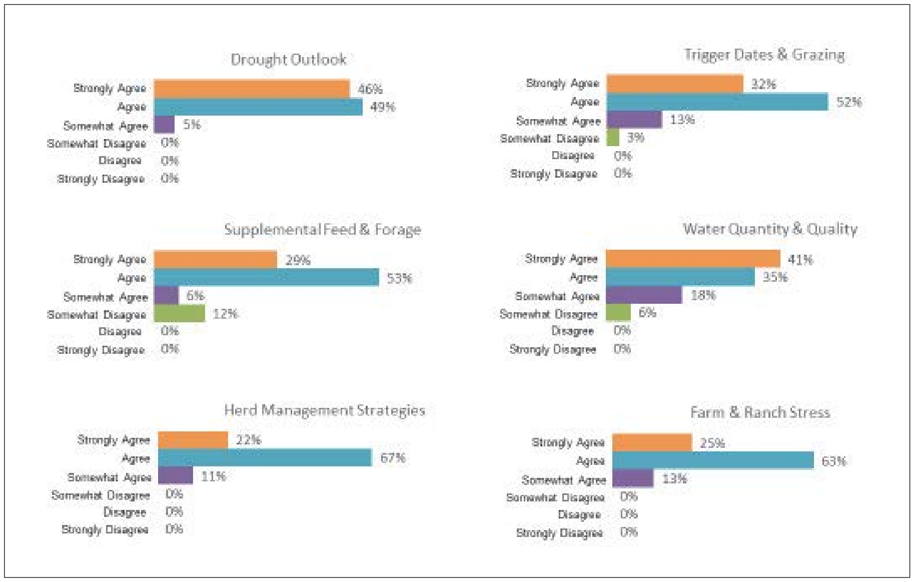

Figure 1. Participant rating of knowledge increase for the six sessions in the Preparing Your Ranch for Drought webinar series.

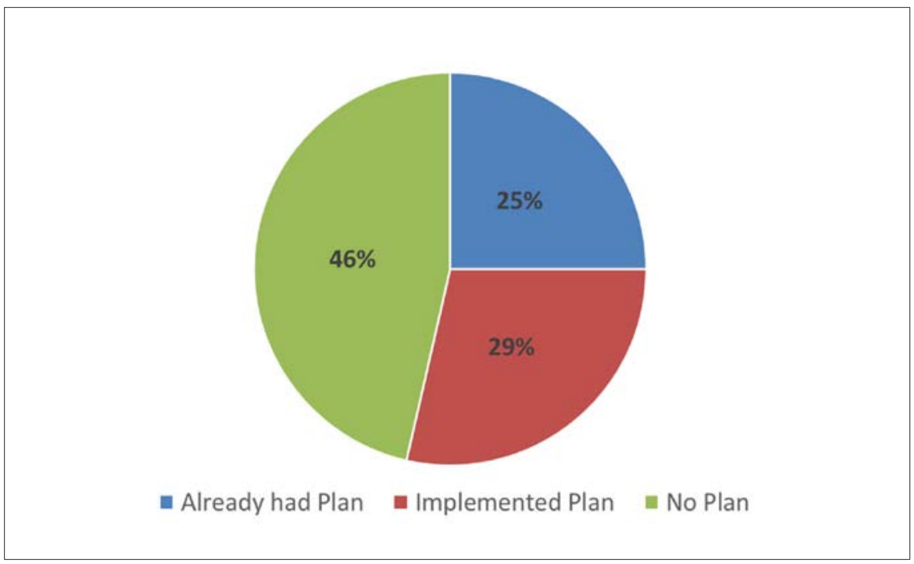

Figure 2. Status of drought plans for individuals following participation in the Preparing Your Ranch for Drought webinars.

(Photo by Michael Undi, NDSU)

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(Photo by Carl Dahlen, NDSU)

(Photo by Karl Hoppe, NDSU)

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